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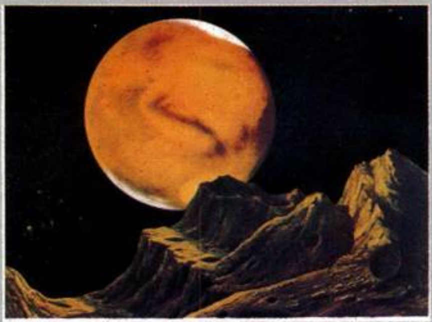

Mars as Seen From Deimos

Actual Poster Size: 17" x 22"

Painted by Victor Costanzo, the red planet Mars and its outer satellite Deimos are set against a real stellar background. To the lower left of Mars is the Hyades, a star cluster in Taurus; at upper right is the constellation Aries. Varnished; suitable for framing. $1.25 each.

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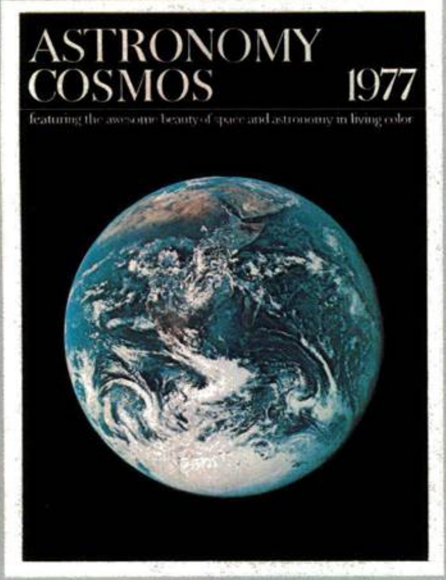
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BEHIND THE SCENES

We're sure many of you are interested in what goes on "Behind the Scenes" at ASTRONOMY: Why and how we select certain articles . . . how an artist creates a painting of an object that's never been photographed close-up . . . what's involved in actually producing and printing ASTRONOMY every month . . . how your circulation problems are solved . . . .

Every few months we'll run a "memo" written by someone on ASTRONOMY's staff telling you a little about his or her job, and what's going on "Behind the Scenes". So, leading off this month is our editor, Richard Berry.

Penny Oldenburger

Penny Oldenburger
Managing Editor

You've seen my work far more often than you think . . . you've heard me on telescopes, darkrooms, the moon, telescope making, astrophotography, and the modern revolution in astronomy. I'm also behind many of the diagrams, picture choices, some of the artwork (Mark Paternostro and I confer extensively over each painting he does), some captions and layout of individual articles and the whole magazine. Most important though, I'm responsible (ultimately) for the articles that go into each new issue of ASTRONOMY.

That means we're constantly looking at what's going on in astronomy, and we're constantly listening to you, ASTRONOMY's readers, so that we can bring you the very best, most interesting, colorful and most exciting magazine possible.

More than one reader, we're sure, has had this happen: You opened your mailbox, found ASTRONOMY waiting for you . . . then quickly scanning the contents said to yourself, "Ah, that article is about just what I wanted to know!" Then when you read it recognition dawned: "That's exactly what I asked when I wrote that letter six months ago. This article is the answer!"

That's just what happens — we base lots of our articles on the questions you ask. Of course, if just one or two of you ask a question we think nobody else will be interested in, we try to answer your questions personally.

But that poses a problem for us: We print more than 85,000 copies of ASTRONOMY every month, and something like 1-3/4 people read each copy — that's 150,000 curious people! You send in a lot of questions, and a lot of good ideas too. We read them all (in fact more than one editor often reads your letter), but we simply can't answer them all individually. So if you've written and we haven't answered, please don't think your letter fell into a black hole! We did read your letter . . . and who knows, maybe next month's Gazer's Gazette will be based on it! Meanwhile, keep an eye on In Focus; your letter may turn up there!

As ASTRONOMY moves through its fifth year of growth and publication, we face a peculiar dilemma. Many of you have been with us since the beginning, and many more for three, two or one years. As you've learned more about astronomy, perhaps bought and used your first telescope, and learned the constellations and what to look for in the sky, you've asked us for articles with "more to them". ASTRONOMY has grown with you.

We at ASTRONOMY believe nothing in astronomy should remain a mystery — simply because there are no ideas so obscure that they can't be said in plain language (just tell internal revenue that one!). So we're going to continue working on bringing you the finest, most authoritative — and most understandable — science articles ever written. Don't think for a minute we're going to scrimp on content — we'll fearlessly tackle the most exciting and intriguing topics astronomy has to offer.

Meanwhile, we're bringing Stellar Frontiers back stronger than ever: Each month we hope to explore some part of the unknown frontier of modern astronomy — some problem that hasn't been answered. If you've been reading ASTRONOMY for a while, we think you'll appreciate the "new" Stellar Frontiers; we hope it will become the very best astronomical essay published anywhere on a monthly basis. And if you're a new ASTRONOMY reader, you'll soon find it all makes sense to you.

Finally, we're really excited about our regular departments: Equipment Atlas, Gazer's Gazette and Photography in Astronomy. Your warm response to recent articles has been very gratifying to all of us. In particular, you helped us shape the "Building A 6" Telescope" series to meet your needs. The new series just starting ("What's Inside Your Telescope?") will, we hope, help you build, buy or adjust a telescope, or just plain enjoy looking through a telescope more knowledgeably. And there will be more on building your own telescopes, mountings and other equipment from time to time.

We'll also try to put the information you need to buy a fine telescope in those pages: It's one of those things you keep asking, and there just are no simple "brand name" answers because every observer is unique. What you must do is define your specific interests; then ask yourself what you hope to do with a telescope after you've unpacked it . . . Oops, I've just started to write an article! Well, you'll see it in another month or two. Meanwhile, keep us in mind and drop us a line . . . we'll be listening!

Richard Berry

Richard Berry
Editor

ASTRONOMY

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Managing Editor
Penny Oldenburger

Editor
Richard Berry

Associate Editor
Henry J. Phillips

Staff Writer and
Astro-News Editor
Mary Jane Lamers

Contributing Editors
James Mullaney
James E. Oberg

Contributing Photographers
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Jodi Groth
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COVER

Spring means galaxies! Sweeping across the night sky from Ursa Major and into Coma Berenices and Virgo lie hundreds of the tiny faint spirals and delicate elliptical forms that we, in the 20th century, know are vast "island universes" — star cities as large as our own galaxy and incredibly remote. This month ASTRONOMY explores the spring constellations, and takes you deep into the central swarm of the Virgo cluster of galaxies where astrophotographers have a field day. Lest you think all galaxian mysteries are solved, you'll see they aren't in Stellar Frontiers! And if a journey in imagination isn't good enough for you, take a look at "Beyond Centauri" — maybe you'll really get to go there yourself. Our cover photograph of NGC-253 in Sculptor was made with the 48 inch Schmidt telescope at Hale Observatories, copyright© 1961 by California Institute of Technology and Carnegie Institution of Washington.

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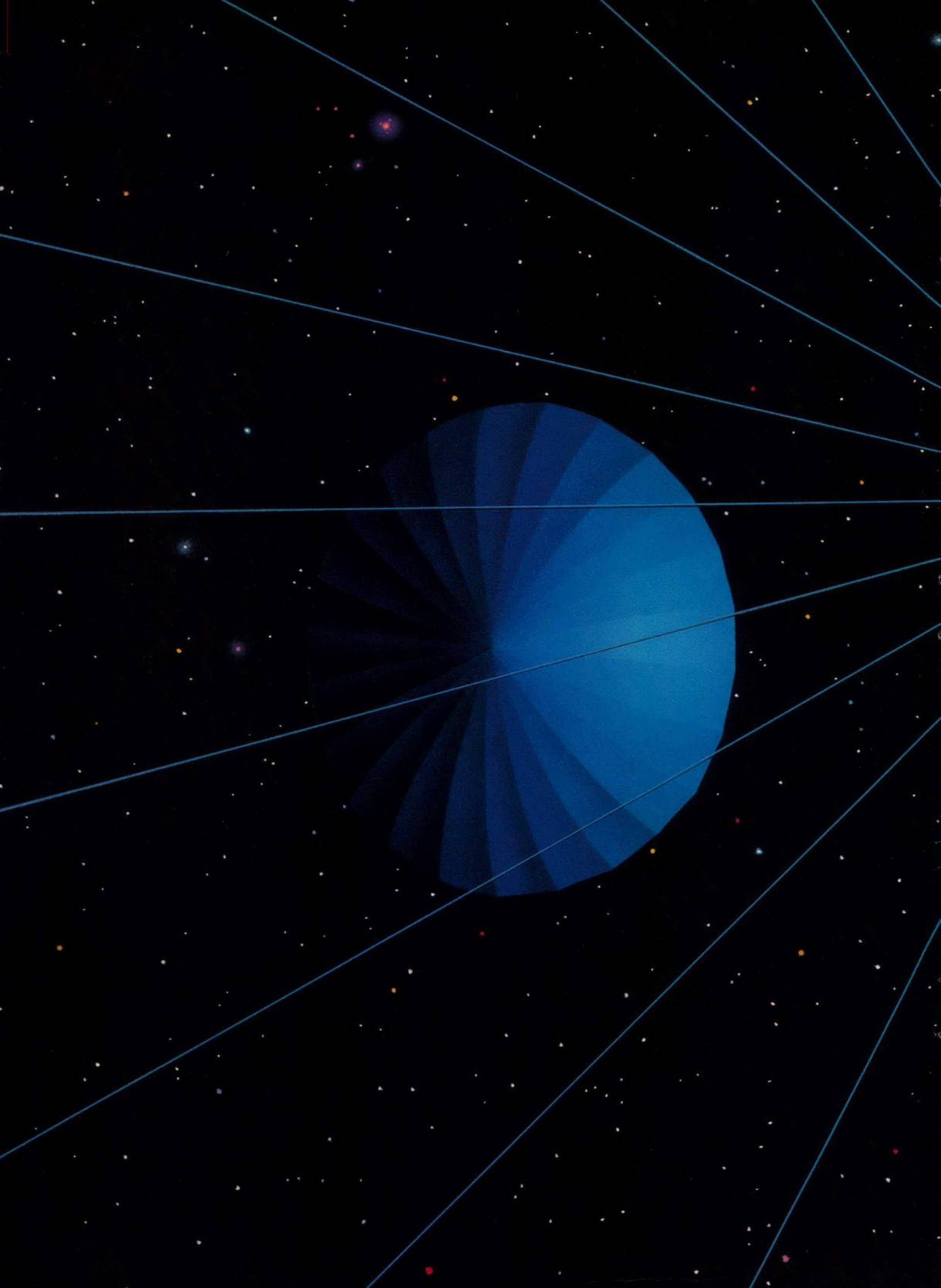
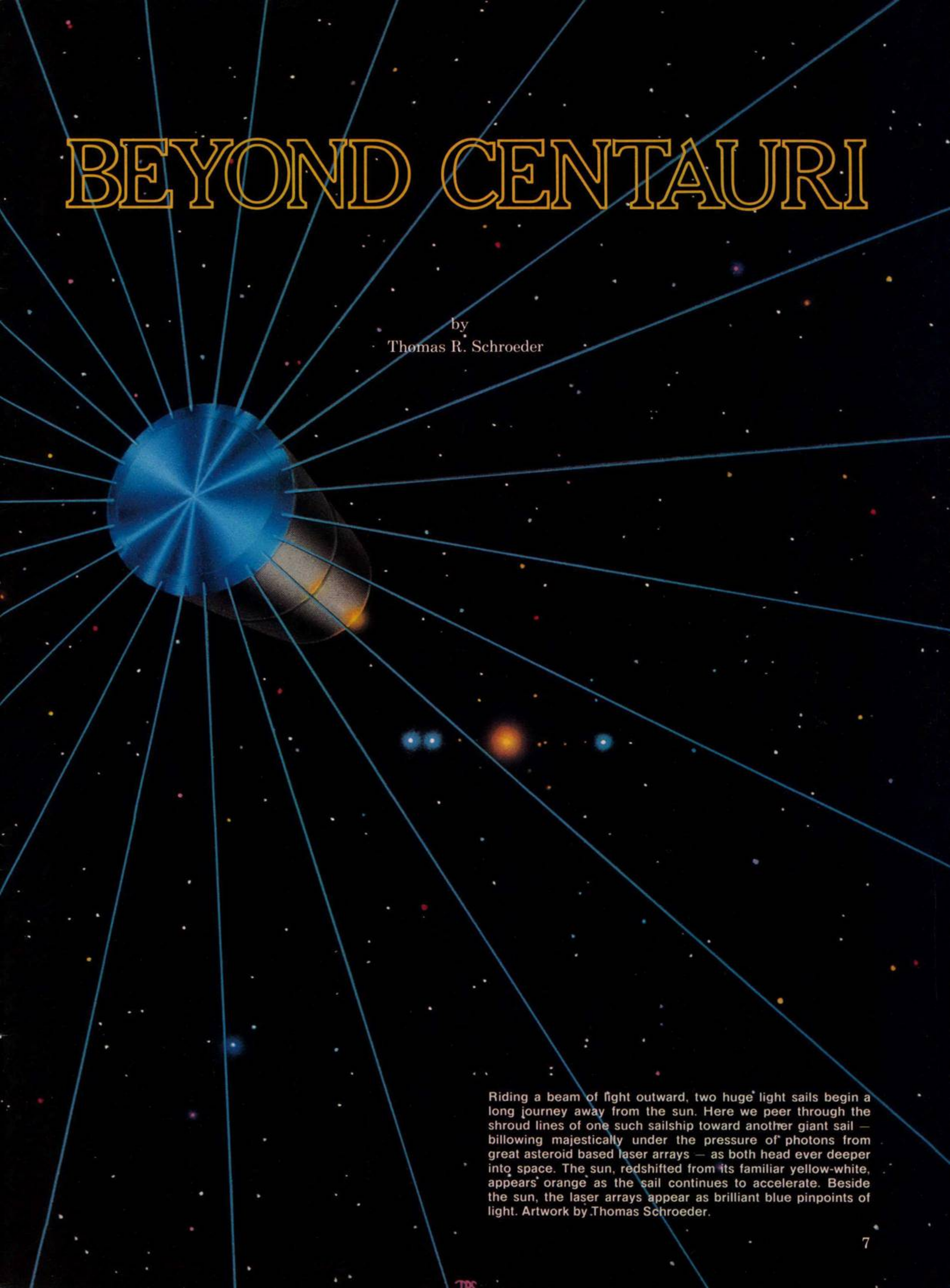
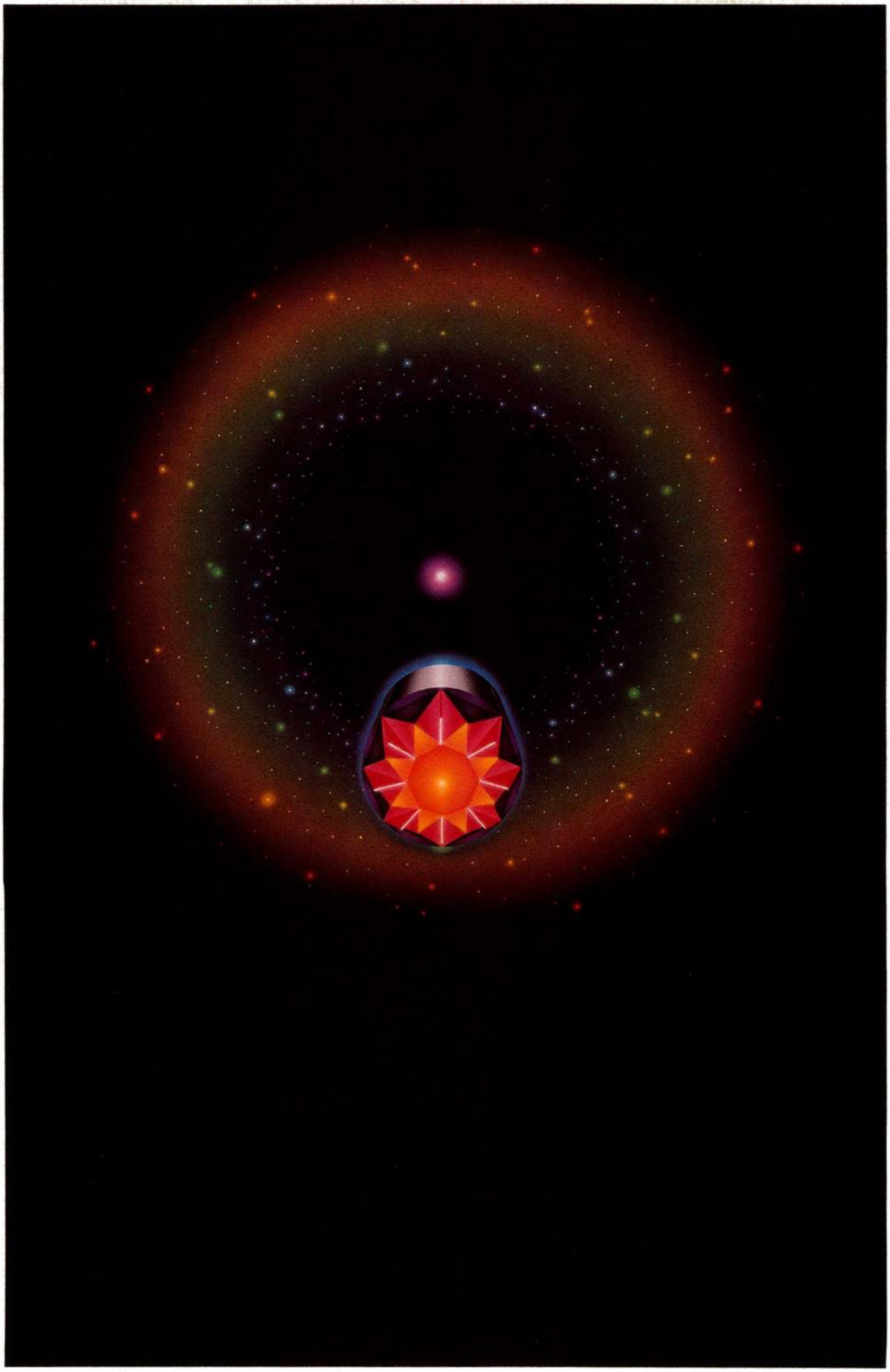


BEYOND CENTAURI

by
Thomas R. Schroeder



Riding a beam of light outward, two huge light sails begin a long journey away from the sun. Here we peer through the shroud lines of one such sailship toward another giant sail — billowing majestically under the pressure of photons from great asteroid based laser arrays — as both head ever deeper into space. The sun, redshifted from its familiar yellow-white, appears orange as the sail continues to accelerate. Beside the sun, the laser arrays appear as brilliant blue pinpoints of light. Artwork by Thomas Schroeder.



In contemplating an interstellar expedition, there are two facts which are well known and very important. The first is that the stars are extremely far away: The gulfs separating stars are so vast that the speed of light seems like a feeble crawl. The second great truth is that rockets, to a large extent, are impractical as a means of travel to the stars. The most formidable difficulty is keeping the fuel weight down, while still producing the greatest acceleration possible. A number of studies have suggested that the greatest velocity a rocket would likely ever attain is about 1/10 the speed of light, or a mere 18,600 miles per second (30,000 kilometers per second). Consequently, a round trip to Alpha Centauri, our nearest stellar neighbor, would take 90 years — minimum!

Fortunately, these obstacles are not as serious as you might think. Two recent propulsion studies (Projects Orion and Daedalus; see "Slow Boat to Centauri", ASTRONOMY, August 1977) indicate that the seemingly impossible trip to a nearby star system is within the grasp of our present technology. Furthermore, by combining these current propulsion techniques with the far older notion of building very large vessels that can last for generations, we find that there *is* a feasible method of interstellar transport.

But, at best, a multigeneration starship of this type would be a cumbersome solution to the problems of extrasolar travel. Those mile long arks may never be built because there are simpler, cheaper, more efficient ways of getting to the stars.

At the moment our attitude toward starflight has been conditioned by ships capable of only 1/10 the speed of light, and the human lifespan. If the engineers can do nothing more to improve a rocket's velocity, then perhaps medical science may provide two rather obvious solutions.

Advances in geriatric and longevity research could supply a partial form of immortality long before we are ready to build a starship. This prospect is not as ridiculous as it first sounds. Death is an evolutionary rather than a biological necessity; evolution favors creatures that die, provided they die after their reproductive age has passed. Thus a species can be modified through mutation and by natural selection to meet changing conditions. Once our ancestors began using tools to change their environment, they greatly increased their life expectancy. At least some physicians are now seriously considering several likely avenues toward the eventual elimination of death. Two recent examples follow:

A diamond fiber ramjet blazes starward at 90 percent light speed, the ship's engines fueled by interstellar hydrogen gathered by intense magnetic field scoops. The glowing bright red, triangular panel on the aft end of the vessel dissipates waste heat. Intense friction among incoming particles creates a bright spot directly dead ahead. Meanwhile, all that remains of the visible universe is a narrow band of stars; all the others have been red- or blue- shifted into invisibility. Artwork by Thomas Schroeder.

In 1974, researchers in East Lansing, Mich. reportedly tested a drug — on flies — that might be able to triple the human lifespan. After flies the biophysicists plan to concentrate on mice, with the hope of starting tests on people around 1984. The intent is to reduce the normal human body temperature from 98.6 degrees Fahrenheit to about 86 degrees Fahrenheit, thus slowing the aging process and extending life.

A slightly different attack upon aging received much fanfare in 1976. Johan Bjorksten, president of Bjorksten Research Laboratories, while speaking before a meeting of the American Chemical Society, stated that aging occurs when two molecules in a gene (the basic unit of heredity) become hooked together by a process called *cross linking*. As more molecules become linked together, the cells that contain them do not function as well. What Bjorksten and his fellow scientists intend to find is an enzyme that could dissolve the bond linking the molecules, reversing the aging process. A few such enzymes are now being tested. In fact, a variety of different substances are under examination by independent research teams scattered around the world, and some show promising results. Advances in genetic engineering, prosthetic devices and transplantation surgery all may help to hold deteriorating bodies together for longer and longer periods of time.

Immortality and the preservation of youth is such an alluring dream that humans will surely always search for it. Whether success is desirable is another matter. What possible side effects could be expected from longevity? How might it influence our social and economic foundations? If a methuselah enzyme were available only to the very rich, our entire social structure could become hideously stratified. The top of such a society might well be occupied by a few billionaire immortals (who might gradually tie up more and more of the country's wealth), while the poor mortals would dwell at the bottom levels. An alternative might be government intervention, in which case the public might never know about the drug. In time, however, a few mortals could become suspicious about the ageless appearance of the nation's leaders!

Immortality might not be the solution to interstellar spaceflight. A crew of immortals — no matter how well balanced and carefully selected — might find each other's company intolerable aboard a small spacecraft over a long flight. Murders among crewmembers may be the ultimate limit on travel to the stars!

Suspended animation, so beloved by science fiction writers, is another obvious medical approach to the problem of lengthy flight times. Drastic slowing of the body's metabolism, with the aid of low temperatures, is now medically commonplace in some types of surgery — though, of course, it has only been done for just a few hours. But it takes no great stretch of the imagination to visualize a shipload of hibernating astronauts, waiting for years in cold storage to be automatically awakened upon arrival in some exotic star system. A sleeper vessel could be smaller and fully automatic because, of course, the crew requires no more room than their refrigeration cubicles.

As attractive as this sounds, there is a major drawback in quick freezing a whole human being — and that is *ice*. Anyone who has left a milk bottle outside on a freezing cold night can testify that water has a greater volume when frozen. During cryohibernation, freezing water inside the cells expands until the cell ruptures from within. Antifreezing drugs should be ruled out; saturating the body with lethal levels of chemicals is not the answer. However, American astronomer Carl Sagan and Swedish biologist Carl-Goren Heden have suggested a possible solution: Frozen water retains nearly the same density as the liquid under 3,000 atmospheres. The difficulty then becomes safely pressurizing an astronaut to a surrounding air pressure of several thousand atmospheres and then quick freezing him (or her) for the long journey. This could possibly be done by using a mixture of gases similar to those used by divers in deep sea habitats.

Besides cellular disruption, there is a radiation problem — not the normal background cosmic radiation, but rather the natural radioactive atoms within everyone's body. In a state of cryogenic preservation, these radioactive atoms would begin to destroy surrounding tissue which — being frozen — could not be replaced. This naturally sets an upper limit to the length of time for cryostorage. For a human being that may only be a few thousand years!

If the Rip Van Winkle method is not to your taste, a clever medical approach to star travel has been suggested by science fiction writer Arthur C. Clarke. Clarke envisaged a starship that carries only human germ cells. The eggs would be fertilized automatically about 20 years before the end of the voyage. The resulting children would be cared for and educated by cybernetic nurses. Knowing no parents. the young people will mature, be trained and carry out their duties on the mobile worldlet. Such techniques are already being hinted at by today's research. Would a future society commit their unconceived children to such a project? We certainly don't know now!

Medical approaches are only one possibility. The whole idea of ships plodding along at only 18,000 miles per second, with or without the use of suspended animation, is not as appealing as a *relativistic* starship.

According to Albert Einstein's Special Theory of Relativity, the speed of light in a vacuum is the absolute limit of velocity within our universe. If a space vehicle could be accelerated toward the speed of light, the familiar laws of motion which Newton stated definitely are simply not adequate to describe what occurs. Mass no longer is constant, but increases with speed; the ship's length (in the direction of motion) shrinks and the energy required to propel it rises toward infinity. Along with these curious results is the remarkable *time dilation effect*. Both Einstein's equations and experimental physics show that time passes *slower* for fast moving objects.

To demonstrate, suppose we track a vessel for 10 light-years at a steady speed of 70 percent of the speed of light. To an observer on Earth, the passage takes slightly over 14 years, while the crew of the ship experiences a little under 11 years by *their* clocks. At greater speeds the internal motions within the ship slow down even further. If the speed were increased to 90 percent of the speed of light, over the same 10 light-years, the passage of the vessel as seen by an outside observer takes 11 years. The crew, however, experiences only about four years.

Unfortunately, this form of time travel is strictly one-way. The people at home who paid for it will all continue to age normally.

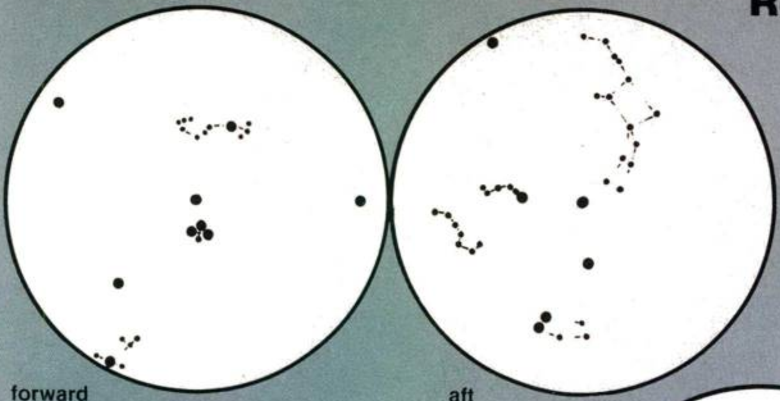
Sagan, an ardent defender of the feasibility of interstellar travel, calculated that a vehicle taking advantage of this stretching of time will reach the nearer stars, like Tau Ceti, within five years. With an acceleration no greater than that of Earth's gravity, the 650 light-years to Deneb will take about 13 years from the crew's lives. The 27,000 light-years to the center of our galaxy could be reached in 21 ship years, and the 2-1/4 million light-years to the Andromeda galaxy could be reached in only 29 years, ship time.

However, long before time measurements aboard the ship begin to differ greatly from those on Earth, a navigation problem will arise. This is largely a result of the Doppler effect.

The *Doppler effect* is the shift in observed wavelength from an emitting object (in this case a star) when the observer's velocity changes. If we move away from a star, we see its light redden as it's shifted into the infrared or lower frequencies of the spectrum. By moving toward a star, we see its light become increasingly bluer as the light shifts into the ultraviolet or higher frequency end of the electromagnetic spectrum. The effects become more extreme as we approach light speed.

After departing from the solar system, astronauts will see the color of our sun slowly change from yellow to orange and then to red until, at around 30 percent the speed of light, old Sol will vanish to the naked eye. As the spacecraft continues accelerating, the black void will persist in engulfing an expanding circle of reddening stars behind the ship. If the target star is similar to our sun, its yellowish hue will shift through green, blue and then violet. At about 36 percent light speed, the light of the destination star disappears from the visible spectrum. Now the ship is flying into a narrow cone of blackness ahead with a larger one astern. Eventually our relativistic astronauts will see most of the stars gathering into a multicolored ring ahead of them.

Relativity: A Trip to the Stars


forward
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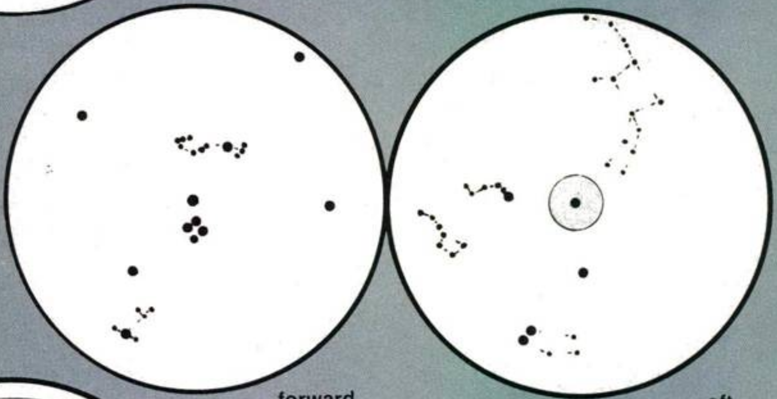
0%c

Nonmoving ship
Length: 1000m
Hour: 60 min.
Mass: 10,000 tons

30%c

90,000 km/sec
Length: 953m
Hour: 57 min.
Mass: 10,480 tons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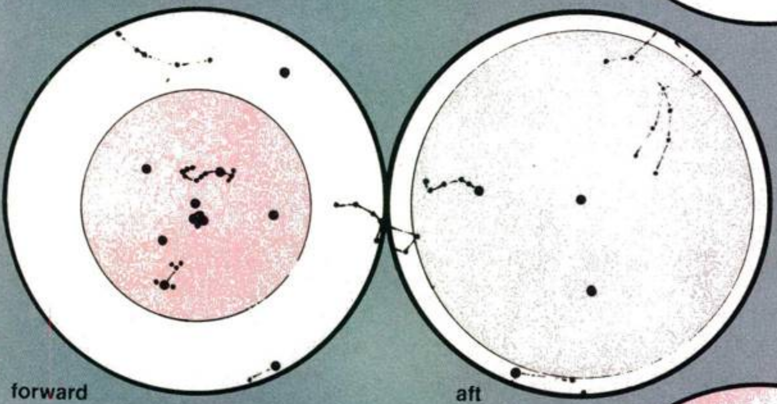
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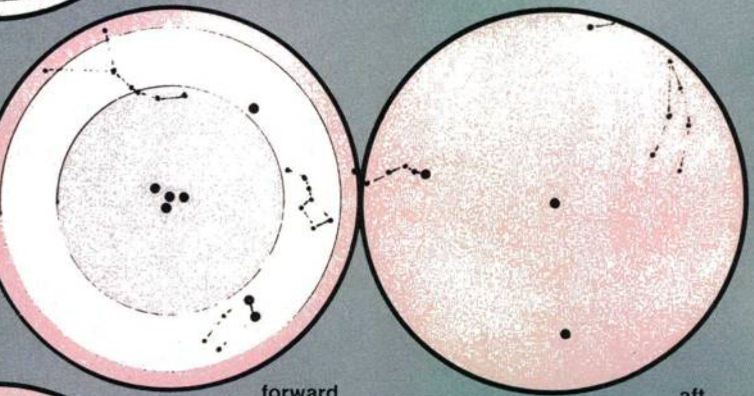
50%c

150,000 km/sec
Length: 866m
Hour: 52 min.
Mass: 11,500 tons

70%c

210,000 km/sec
Length: 714m
Hour: 42 min.
Mass: 13,900 tons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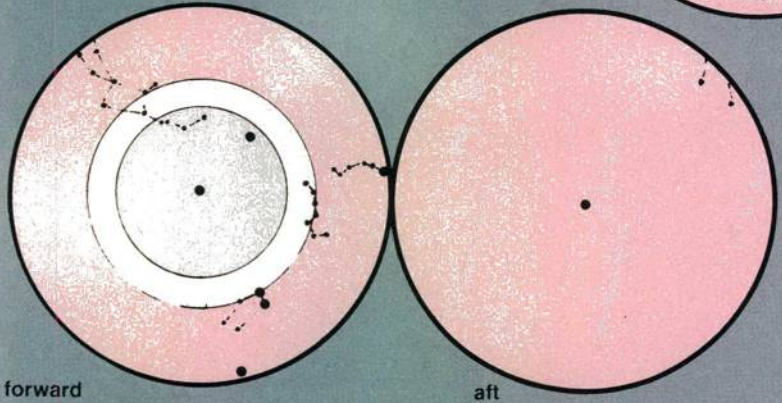
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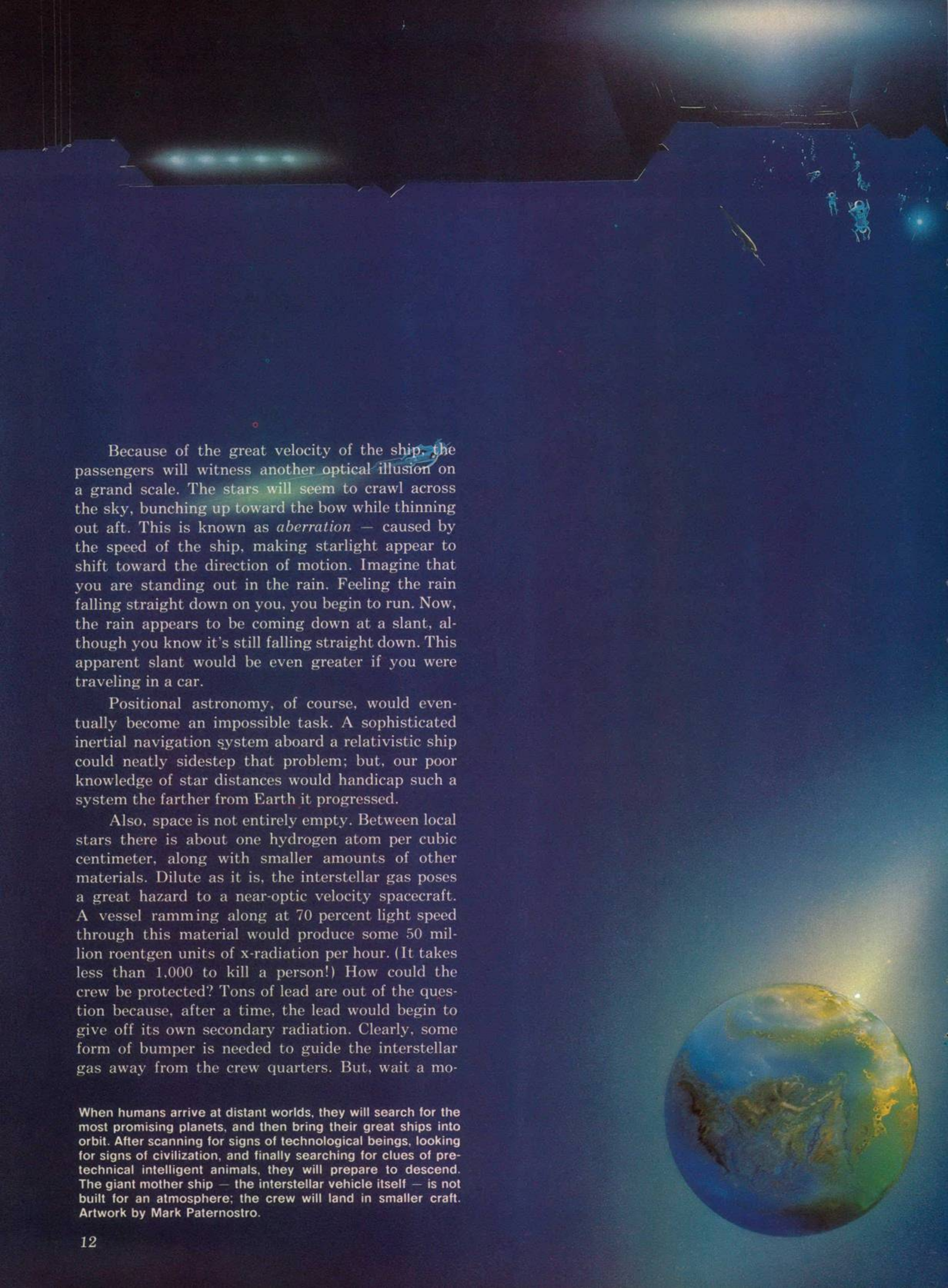
90%c

270,000 km/sec
Length: 435m
Hour: 26 min.
Mass: 22,900 tons

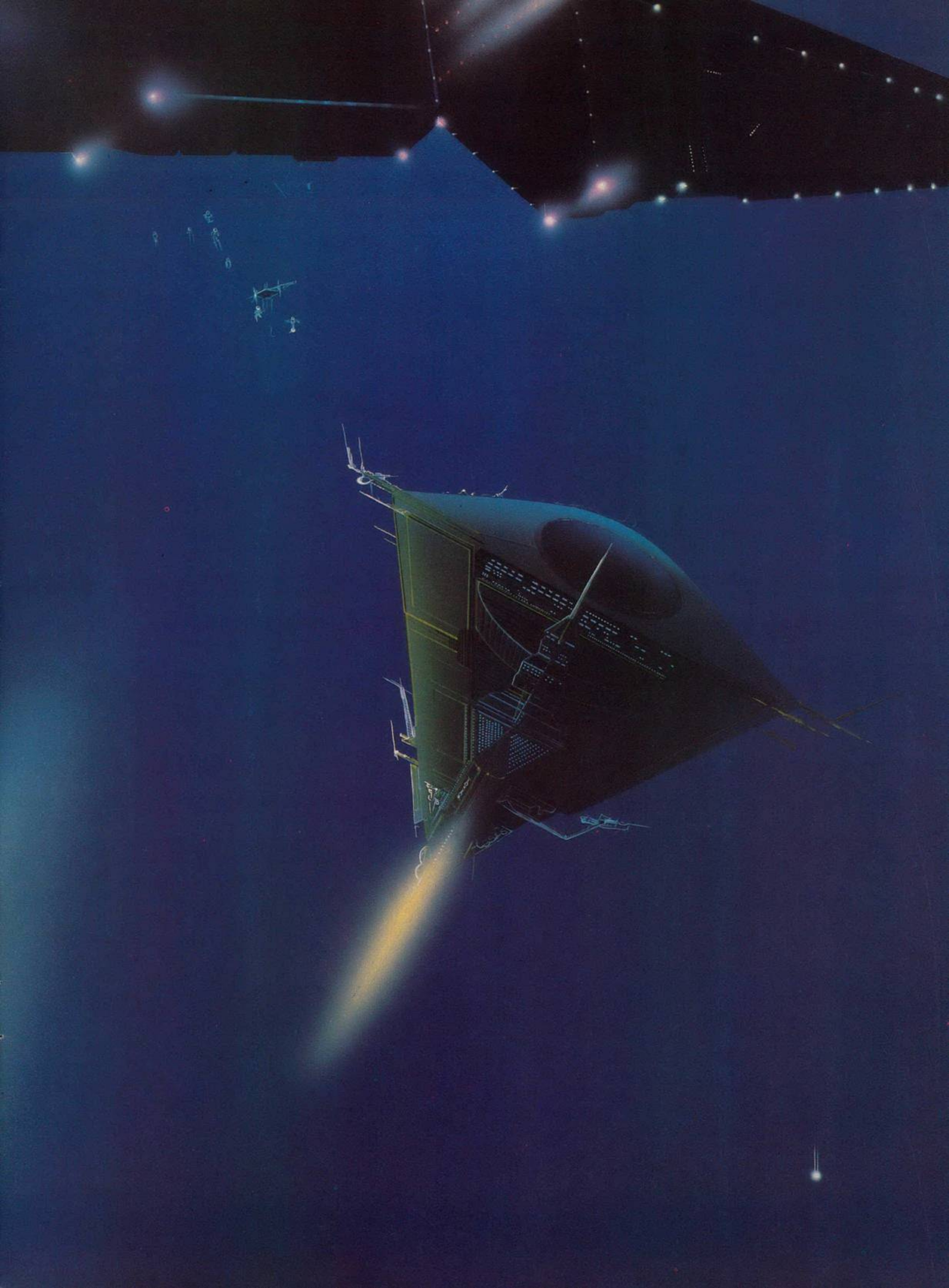


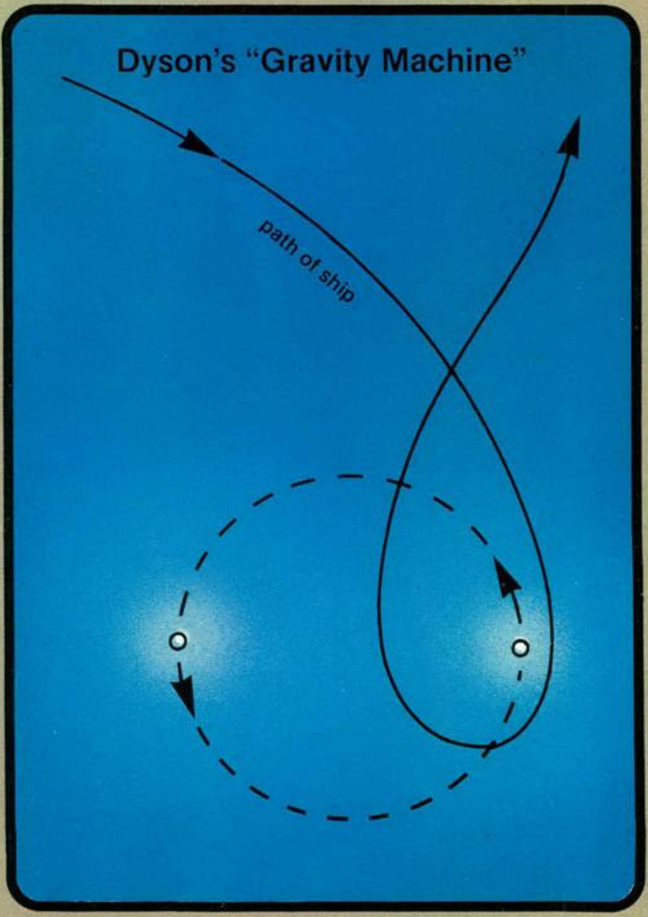
Because of the great velocity of the ship, the passengers will witness another optical illusion on a grand scale. The stars will seem to crawl across the sky, bunching up toward the bow while thinning out aft. This is known as *aberration* — caused by the speed of the ship, making starlight appear to shift toward the direction of motion. Imagine that you are standing out in the rain. Feeling the rain falling straight down on you, you begin to run. Now, the rain appears to be coming down at a slant, although you know it's still falling straight down. This apparent slant would be even greater if you were traveling in a car.

Positional astronomy, of course, would eventually become an impossible task. A sophisticated inertial navigation system aboard a relativistic ship could neatly sidestep that problem; but, our poor knowledge of star distances would handicap such a system the farther from Earth it progressed.

Also, space is not entirely empty. Between local stars there is about one hydrogen atom per cubic centimeter, along with smaller amounts of other materials. Dilute as it is, the interstellar gas poses a great hazard to a near-optic velocity spacecraft. A vessel ramming along at 70 percent light speed through this material would produce some 50 million roentgen units of x-radiation per hour. (It takes less than 1,000 to kill a person!) How could the crew be protected? Tons of lead are out of the question because, after a time, the lead would begin to give off its own secondary radiation. Clearly, some form of bumper is needed to guide the interstellar gas away from the crew quarters. But, wait a mo-

When humans arrive at distant worlds, they will search for the most promising planets, and then bring their great ships into orbit. After scanning for signs of technological beings, looking for signs of civilization, and finally searching for clues of pretechnical intelligent animals, they will prepare to descend. The giant mother ship — the interstellar vehicle itself — is not built for an atmosphere; the crew will land in smaller craft. Artwork by Mark Paternostro.





ment — since the gas must be controlled anyway, why not put it to good use *as fuel*?

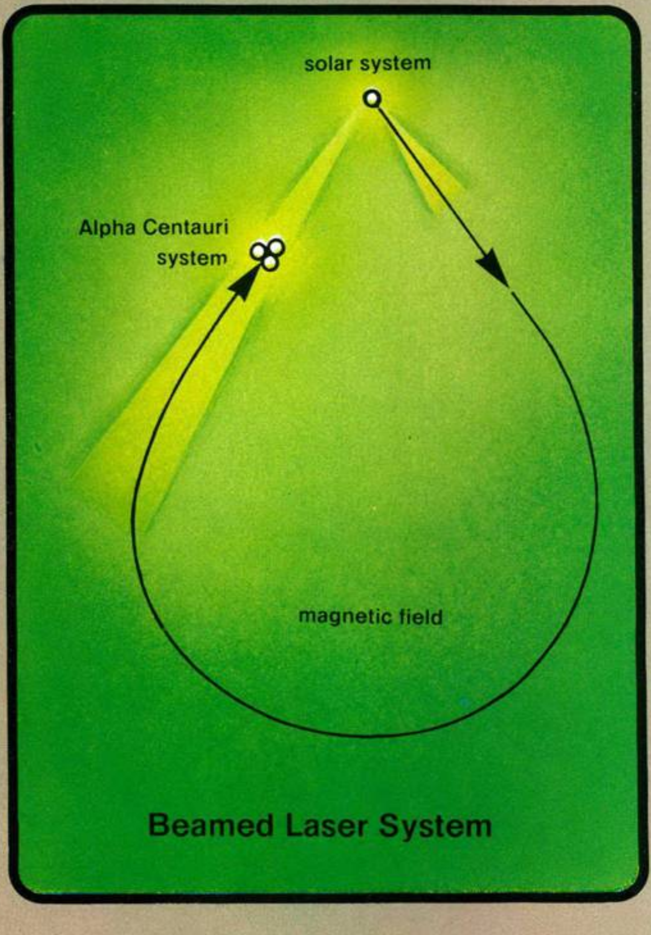
The interstellar ramjet was proposed in 1960 by American physicist Robert W. Bussard. The beauty of this device is that it does away with the burdening fuel problems of the rocket, allowing it to reach relativistic speeds. Bussard's ramjet scoops up the hydrogen scattered in interstellar space and delivers it to a fusion reactor which spews out the resulting heated gases in a propulsive jet, thus giving the starship unlimited range. According to his calculations, a little 1,100 ton spaceship consisting mostly of payload would require a collecting scoop diameter of about 1,240 miles (2,000km). The scoop itself is a *magnetic deflector* produced by the ship. As the ramjet speeds up, a smaller field will be needed because the vessel's efficiency increases at higher velocities. A steady laser barrage emitted from the ship could impart a small electric charge to ionize all neutral atoms as well as vaporize small bits of dust and debris that might otherwise be a hazard. At its destination, the ship could decelerate by adjusting the intake field to act like a magnetic drogue parachute.

Almost 10 years after Bussard's proposal, Dr. Anthony Martin of London's City University critically evaluated the ramjet concept and found some limitations. It appears that particles trapped in the scoop's field will radiate away some of their energy as they collide on the way to the reactor. There will also be incomplete fusion of the hydrogen within the reactor. Together, these energy losses could prevent acceleration beyond 90 percent of the speed of light.

In addition, Martin's calculations show that the field strength must increase as the ship's speed increases, and this would have a tendency to burst the ramjet's hull. Therefore, beyond a certain point, the acceleration of the vessel must be reduced to avoid structural damage. In building a ramjet, it is extremely important to use very strong materials: The stronger the substance used, the greater the acceleration time. A ramjet constructed of aluminum could withstand a constant acceleration of one G over a distance of only 12-1/2 light-years before it would have to reduce its speed. If instead the ship were made of copper, it could survive a 1,000 light-year journey before its stress limits would be reached. Being extremely optimistic, Martin suggested that within the next century, it might be possible to synthetically produce a *spun diamond fiber*! This thread could be woven into diamond fiber composites and bonded with a superhigh strength resin. A ramjet constructed of such diamond fiber plates would be able to make an incredible 3,300 light-year trek before needing to brake.

Martin conjured up a romantic vision: A glittering diamond fiber ramjet whose magnetic net helps feed an engine that runs on stardust!

In 1974, Alan Bond, a British propulsion engineer (and one of the originators of Project Daedalus), pictured a slightly less poetic version of the same vehicle. Bond named his system RAIR (Ram Augmented Interstellar Rocket). In effect, it is a



ramjet/rocket hybrid. A fusion rocket using hydrogen isotopes (deuterium and tritium) as fuel produces the thrust, while a ramjet collects interstellar matter which is accelerated electrically in order to boost the rocket's performance. The magnetic scoop derives its power from the fusion drive.

Although the technology is still far beyond today's level, it would seem this type of vessel would be a great deal easier to build than a Bussard ramjet. Needless to say, even at the present theoretical stage, the concept of picking up fuel along the way is too valuable to ignore!

Another ingenious approach to relativistic travel is beamed power propulsion. The idea is to use the photon pressure of a laser to push a huge, highly reflective light-sail to near-optic velocities. Actually, it's like leaving the motor at home. A large laser, either on Earth or in orbit around the sun, would be used to send a beam of light to push the sail. The only difficulty is that once you get your light-sail going, you can't slow it down! However, in 1969, three years after the concept was first published, a Canadian engineer named Philip Norem came up with an elegant solution to this dilemma.

Norem suggested using our galaxy's magnetic fields to make vast midcourse maneuvers. If Norem's designs are put into practice, a voyage to Alpha Centauri might go something like this: A gigantic light sail, 155 miles (250km) across, is launched, using only the solar wind to push it toward the stars. The sail itself is made of a thin, strong, lightweight plastic fabric. Attached by adjustable shroud lines, riding 20 miles (32km) behind the sail is a 1,000 ton spacecraft. As the vessel leaves our star system a small battery of solar pumped lasers, based on asteroids, will beam light at the sail in order to transfer greater momentum to it. This would allow the light-sail to accelerate to about 35 percent of the speed of light over an 8-1/2 year period, as it coasts outward. The spacecraft then relases two long wires over which a charge of a few million volts would be maintained, allowing the vessel to interact with the background magnetic field of the galaxy and veer off course. Traveling majestically for 20 years, the light-sail makes a great arc across interstellar space (making a 180 degree turn, in fact) so that it can approach Alpha Centauri from behind. If all goes well back among the asteroids, a laser arrangement 25 times larger than the launching array is turned on for another 8-1/2 years; the sail can use the beam as a brake. If a similar laser array were set up in the Alpha Centauri system, the travel time should be cut down to 10 years.

Other systems using transmitted power are now under consideration. But because of the divergence of the beam over distance, beamed power systems are only good for trips to relatively close stars and would have to be paid for in gigawatts of raw power. Such lasers would also have frightening military applications.

There are many additional ideas about how starflight might be accomplished — most still very much in the realm of science fiction. Unless backed by careful engineering and physics, most of them are extremely speculative.

Ideally, a perfect starship could accelerate without expelling *any* mass. This concept is usually referred to as "field drive", or "space drive", for lack of a better term. The name implies that propulsion is furnished by some kind of force field.

Using the galactic magnetic field for small midcourse corrections was mentioned earlier. Why not employ electromagnetic forces to interact with that field to accelerate a ship? Nice idea. It's too bad that our galaxy's magnetic field is far too weak, and probably varies from region to region, to be used in this manner.

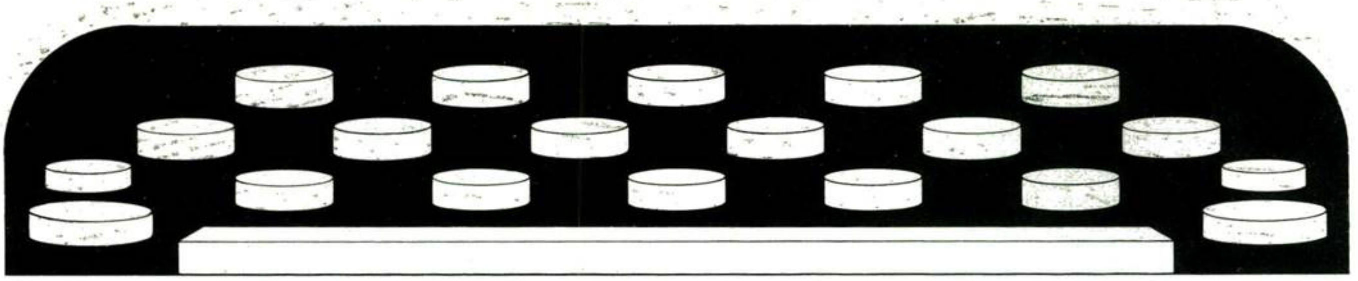
If a field drive vessel were to establish a negative gravitational force, it could react against the mass of the universe as a whole, in order to accelerate. Unfortunately, nobody today knows how to do such a thing. Although antigravity-like forces do occur in the relativity theory (under special conditions), most physicists take it for granted that it's impossible.

Dr. Freeman J. Dyson, a theoretical physicist at Princeton University, has suggested a more conventional approach to using gravitational fields. By approaching close white dwarf binary stars from the correct orbit, a vessel could assume an added thrust equivalent to 1/150 the speed of light. The most remarkable feature of this transaction is that the vehicle undergoes a rapid acceleration of about 10,000Gs with no ill effect on the passengers. Even though there are no double stars of this kind in our neighborhood, Dyson said that a highly advanced culture might be able to imitate nature and construct *its own ultradense binary catapult*!

The foregoing ideas lie on the debatable boundaries of accepted physics. The universe may yet contain unknown sources of energy that a spacecraft might be able to tap — but we should remember that physics and wishful thinking are generally incompatible.

It is said that "necessity is the mother of invention", but in the case of interstellar travel, the dream of starflight may be a greater motivating force than a need could be. With so many theoretical possibilities for starflight, we can probably assume that, if our technology survives itself for another century, at least one of these concepts will be acted upon. Although contemporary physicists tell us that nature has placed a fundamental limit on the speed of our travel, the stars can still be ours — if we really want them.

Thomas R. Schroeder is a freelance artist and writer who has been interested in astronomy and spaceflight for as long as he can remember. He received his B.F.A. from the Minneapolis College of Art and Design in 1975.



IN FOCUS

Sir / I am a recent subscriber to your magazine and enjoy it very much.

Could you please tell me how to do astrophotography with camera and binoculars only? I am thinking of a modest amount of equipment and data on film, light conditions, exposure times, etc. Your help would be sincerely appreciated.

JOHN W. FORACH
Avila Beach, Calif.

Mr. Forach / Generally, there is not very much astrophotography you can do only with camera and binoculars. You would likely find that using your camera alone would provide more pleasing results. You can, of course, obtain good photographs of the moon through binoculars. It is essentially photography through an afocal telescope (see "Photograph the Moon!" in the February 1978 issue). For instance, with 7x35mm binoculars and a camera with a 50mm lens, the effective focal length (camera just pointed into the binoculars) would be 350mm; the focal ratio would be 350mm divided by the aperture of the binoculars — in this case 35mm, or f/10. You can then look up the exposure appropriate for your film and the phase of the moon.

Objects aside from the moon present tracking problems. The 350mm focal length will show star trails as soon as your exposure exceeds two or three seconds. For general advice on the possibilities for telephoto lenses (which are basically similar to the capabilities of a camera/binocular combination), consult "Astrophotography with Telephoto Lenses" in the October 1977 issue, and "City Astrophotography" in the October 1976 issue, for ideas on using a camera alone.

Sir / I've noted with alarm that in recent issues I see an increasing trend toward artwork over photography. Artwork is fine, but a little of it goes a long way — and I'm afraid ASTRONOMY has already gone much too far in this direction. If ASTRONOMY is to live up to its billing as "The World's Most Beautiful Astronomy Magazine", I would suggest more of the natural beauty of the universe as it can only be captured with photography.

HOWARD McCALLON
Huntington Beach, Calif.

Mr. McCallon / We wish to assure you that ASTRONOMY does not intend to abandon photographs. Photographs do bring the most authentic astronomy to our pages. They can't, however, take you inside a nebula or to a time in the past or future. Our paintings can bring these distant places and times directly to you in a way photos cannot. We do thank you for your concern and assure you that we plan to publish plenty of photographs in upcoming issues.

Sir / I found the February 1978 issue especially interesting; the In Focus letters about light pollution hit close to home. I observe with a 60mm refractor in my backyard where there is a street light not 50 feet away that easily outshines the full moon. I observe planets, but concentrate my efforts on Venus, Jupiter and Saturn. When the light was first installed, I was irritated to say the least, but I kept observing and didn't notice that much of a problem. It did, however, slightly decrease the contrast on Jupiter, making it difficult to see some fainter belts. I've also found some measures useful in combating the problem like cupping my hands around the eyepiece to block some of the light and darken the field. In my opinion, a little light pollution does not mean death to planetary observing.

JON KLINEDINST
York, Penn.

Sir / I was dismayed to find a rather glaring error in "Kowal Discovers Miniplanet" (Astro-News, February 1978). The article defined perihelion and aphelion as the "point in its (the miniplanet's) orbit closest and farthest from Earth!" While the object's aphelion undoubtedly represents its greatest distance from Earth, its perihelion does not necessarily represent its closest. This is because Earth may, at the point of the object's perihelion, lie on the other side of the sun. Since the suffix "helion" refers to the sun rather than Earth, this would create a 186,000,000 mile discrepancy. Possibly the terms "per" and "aterra" should have been used.

PAUL G. MEHLIN JR.
Parsippany, N.J.

Sir / I'm inquiring about NASA photographs of Earth that can be framed and hung on the wall. I'm specifically interested in the West Coast area, between Oxnard and Malibu, inland to Conejo Valley (Thousand Oaks), Camarillo and Pt. Mugu.

How do I find out more about the availability of a map, price and size?

MRS. J. BANKS
Camarillo, Calif.

Mrs. Banks / Pictures from NASA's LANDSAT may be obtained by writing the EROS (Earth Resources Observation System) Data Center, Sioux Falls, S.D. 57198; telephone: (605) 594-6511. They will send you descriptions of the sizes and types of pictures you can obtain, order forms and price lists. The EROS Data Center is open to the public daily except Sundays and features an exhibit center and photo gallery. There are 11 EROS Data Reference Files available across the United States where you can view microfilm copies of available photos before you place your order. EROS will send you a list of them if you ask. Gemini, Apollo and Skylab pictures are also available.

Sir / Two errors appeared in the article "The Southern Sky" (November 1977). It stated that Alpha Centauri was a double star and the nearest star. Alpha Centauri is actually a triple star system. One of its members, Proxima Centauri, is closer to Earth by about 0.1 light-years.

SCOTT MILLER
La Canada, Calif.

Mr. Miller / Alpha Centauri is indeed a triple star system, but seen in a small telescope it is a double star — and a very pretty one at that. Lightweight Proxima Centauri is located several degrees from the massive pair, and is 12th magnitude. Certainly the statement in the article was not intended to exclude Proxima from the Alpha Centauri system. See "Stars With Companions: More Than Meets the Eye" in the September 1977 issue for more information.

Ooops!

February 1978, pages 28-29 — on the Planet Finder map, Pluto was plotted as having minus degrees declination when it should have been plus degrees declination.

February 1978, page 31 - the distance given for Mars at the end of February in Sky Almanac — 100 million miles — is incorrect. At the beginning of February, Mars was 62 million miles distant from Earth. By the end of the month, it was some 75 million miles distant. By the end of March, it had receded to 100 million miles.

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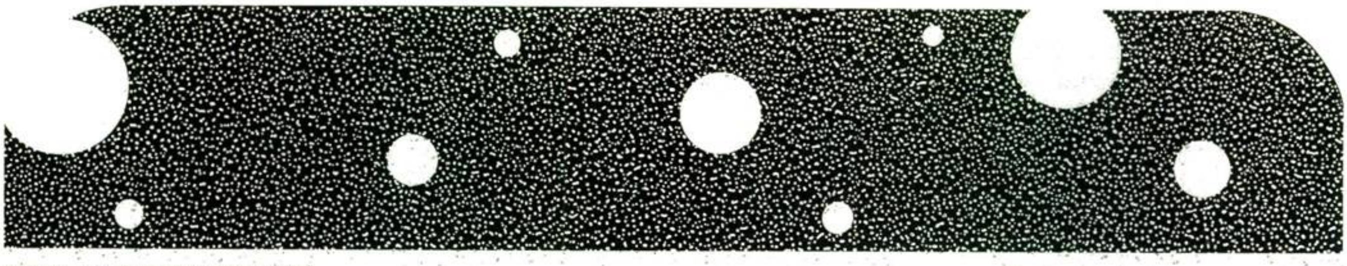


STELLAR FRONTIERS

Brown Dwarfs and Black Holes

by
Jill C. Tarter

Have you ever stepped on an unfamiliar scale in a drugstore or train station and found the scale indicated you weighed more than you knew you did — more than your own bathroom scale registered? An analogous situation happens to astronomers quite frequently, and they are no more pleased about it than you are! In your case, unless your pockets were filled with silver dollars, or the unfamiliar scale was located on Jupiter, the discrepancy between the weight you expected and that registered by the scale wouldn't be too great. A quick mental tally of excess weight (shoes, heavy clothing, etc.), as well as consideration of the inaccuracies of most scales, usually resolves the conflict.

Astronomers are not so lucky. When ordinary astronomical objects such as stars and galaxies occur in large groupings, astronomers can estimate the total mass of the groups by studying the way in which the objects move about one another. In addition, astronomers "know" the masses of individual stars or galaxies, having measured them in more conventional ways on the equivalent of your old reliable bathroom scale. When they compare their *dynamical mass estimate* with the total of the individual masses, the ensembles appear to be grossly overweight. The whole seems to be far more than the sum of its component parts! There is no obvious solution to the dilemma, so astronomers have given it a name: the *missing mass* problem.

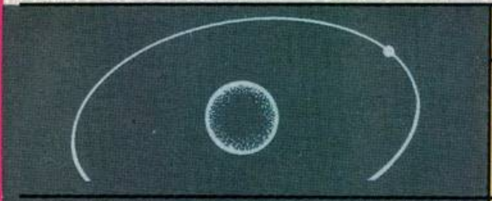
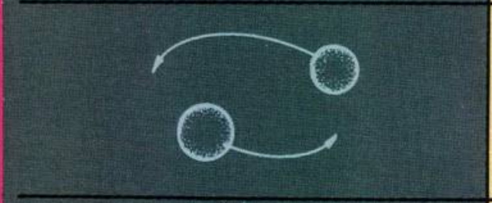
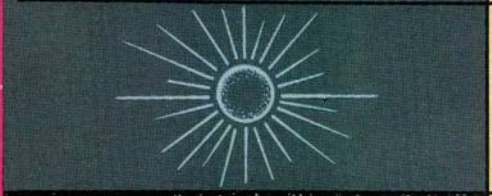
A great deal of thought and observational effort has been expended in an attempt to understand what form of matter might exist within groups of stars and galaxies of various sizes, that yet remains undetected. The problem is not a small or trivial one; in some cases, the missing mass exceeds the conventional observed mass by 10 or 100 times!

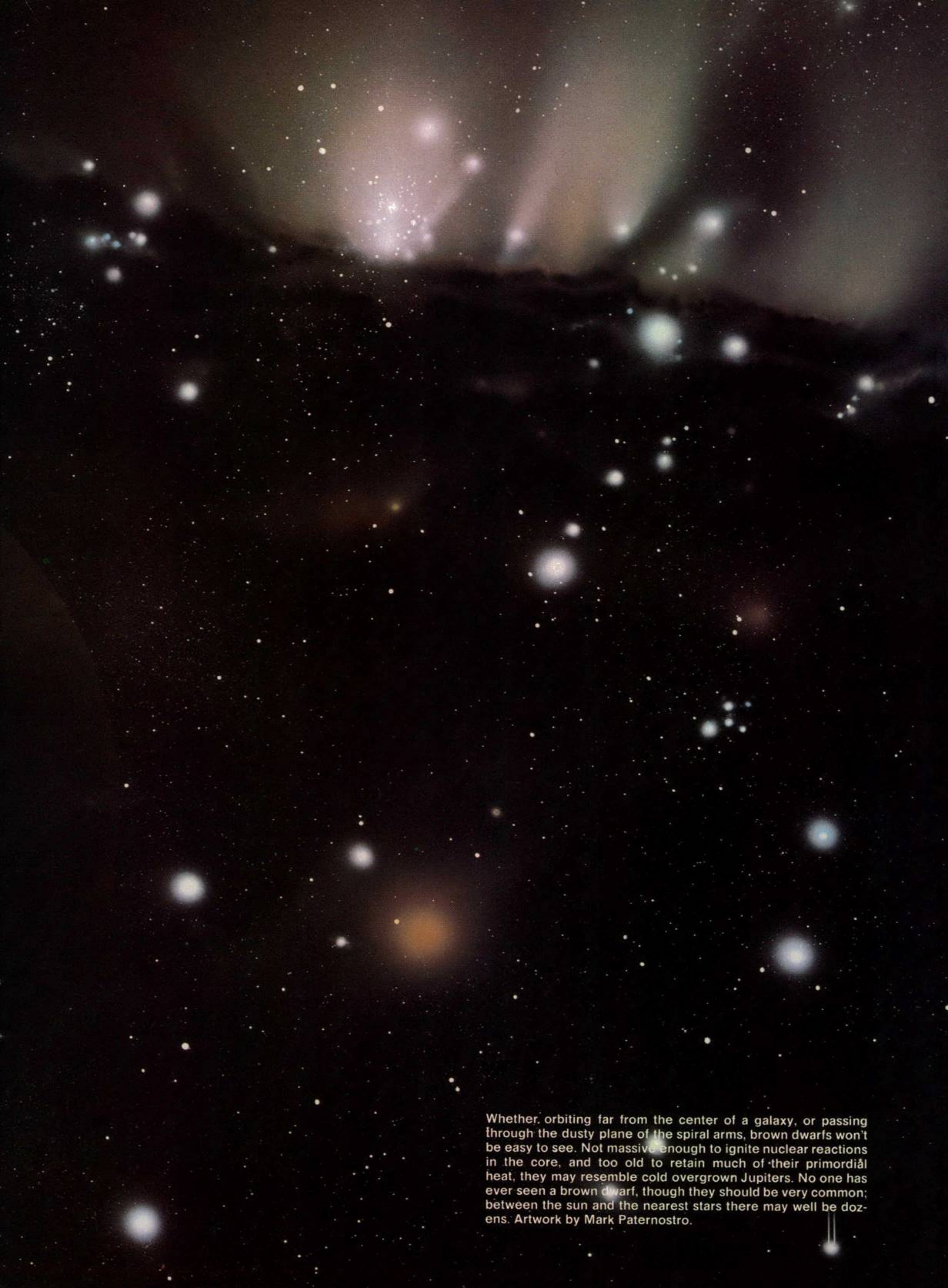
Before looking at some examples of specific missing mass problems, it's important to understand how astronomers measure the mass of anything. The surprising difference you found in your personal scale readouts is simply the difference in the gravitational force of attraction between Earth and two different masses (yourself with and without shoes, clothing, and coin-filled pockets). All the astronomers' "scales" (by which we mean measures of mass) are based on Kepler's laws, which predict how two bodies will move in orbits about each other under the influence of their mutual gravitational attraction (which is proportional to the product of their masses).

With the planets in our solar system, astronomers can get a very accurate estimate of planetary masses by observing the periods and sizes of the orbits of each planet about the sun. The more data we have, and the more accurately determined the precise details of their orbits, the better the mass estimates which result. Stellar masses are more difficult to measure, for although many stars occur close to one another as binary systems and orbit about their common center-of-mass, it is possible for only a few of these binaries to get enough information about the orbits to deduce the masses of the individual stars. Once established, however, the stellar mass scale can be extended to all stars by assuming that all stars which share a common spectroscopic classification also have the same masses. Astronomers have now measured the masses of enough binary stars of sufficiently diverse types to establish a reliable mass-luminosity relation for normal stars. For the major portion of its lifetime, a star's luminosity is proportional to its mass raised to the 4.5 power ($L \propto M^{4.5}$). Therefore, to get a very good estimate of any normal star's mass, it's only necessary to determine its luminosity and/or spectral type.

Galaxies also occur together in binary systems orbiting around each other. Astronomers use one of three strategies to measure galactic masses. Because the orbital period of binary galaxies is so long, astronomers can't follow the motions of the galaxies through an entire orbit, but can only take an instantaneous "snapshot" of their orbital behavior. It is never possible to get enough information about the orbit of any single pair of galaxies to determine the masses of the individual galaxies. However,

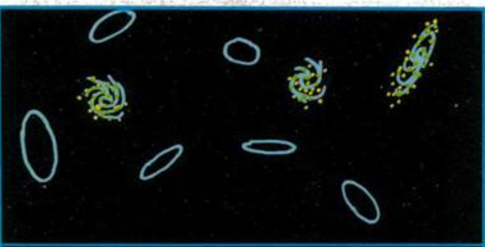
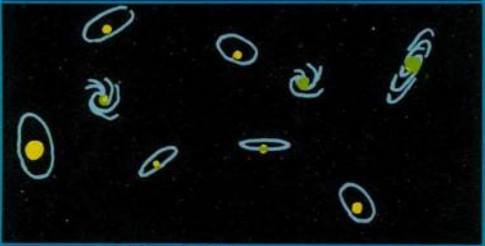
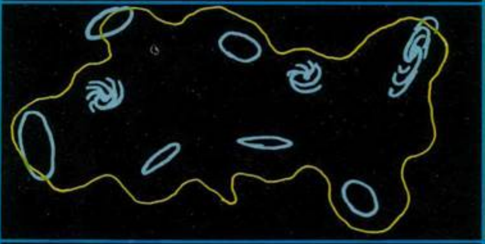
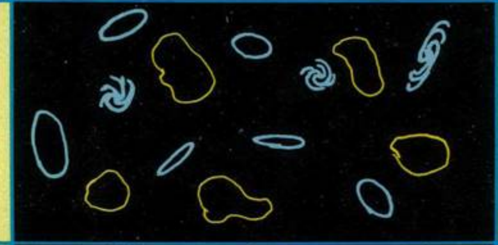
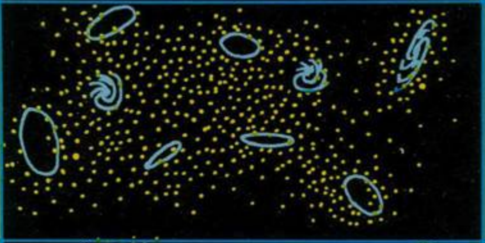
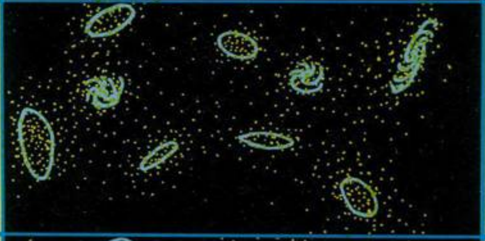
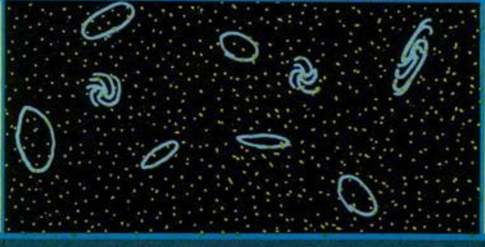
MASS DETERMINATION IN ASTRONOMY

	METHOD	APPLICATION
	Newton's Modification of Kepler's Third Law $a^3/p^2 = 1$ (Kepler's Law) $a^3/p^2 = 1 + m/M$ (Newton's modification)	masses of the planets and their satellites
	Newton's Modification of Kepler's Third Law $a^3/p^2 = M_{star} + M_{star}$	masses of binary stars
	Calibrated Mass/Luminosity Relation $M \propto L^{4.5}$	masses of distant stars and single stars
	Virial Theorem Kinetic Energy = 1/2 Potential Energy $mv^2/2 = GMm/2r$	masses of star clusters
	Newton's Modification of Kepler's Third Law $a^3/p^2 = M_{galaxy\ 1} + m_{galaxy\ 2}$	statistical determination of masses of galaxies
	Virial Theorem Kinetic Energy = 1/2 Potential Energy	masses of individual elliptical galaxies
	Rotation Curve Method $a^3/p^2 = M_{inside\ orbit\ of\ star}$	masses of individual spiral galaxies
	Calibrated Mass/Luminosity Relation $M \propto L$ M/L ratio still a subject of some debate	masses of distant galaxies
	Virial Theorem Kinetic Energy = 1/2 Potential Energy	masses of clusters of galaxies



Whether orbiting far from the center of a galaxy, or passing through the dusty plane of the spiral arms, brown dwarfs won't be easy to see. Not massive enough to ignite nuclear reactions in the core, and too old to retain much of their primordial heat, they may resemble cold overgrown Jupiters. No one has ever seen a brown dwarf, though they should be very common; between the sun and the nearest stars there may well be dozens. Artwork by Mark Paternostro.

WHERE *IS* THE MISSING MASS?

Hiding in the spirals?		**NO** — rich clusters don't have enough spirals to account for the missing mass.
Hiding in the cores of galaxies?		**UNLIKELY** — galaxy cluster motions would be different than observed.
Hiding in hot gaseous halos?		**NO** — there is hot gas (detected by x-rays), but not enough.
Hiding as cold gas clouds?		**NO** — we cannot detect 21cm radio signals expected from cold gas.
Hiding as intergalactic stars?		**NO** — light from these stars could be detected.
Hiding as brown dwarf stars?		**MAYBE** — we expect brown dwarfs to be faint and plentiful.
Hiding as tiny black holes?		**MAYBE** — although invisible, they would fill all space, thus raising the total mass of the universe.

when a large number of binary galaxies are studied, the random orientations should average out in a predictable manner. This statistical approach was first tried by Dr. Thorton Page of NASA in 1952. His results remained unchallenged until 1976, when Dr. E.L. Turner of Harvard attempted to improve the method by removing some observational biases. Both astronomers agree that the masses of galaxies appear to be directly proportional to their total luminosity — a very handy relationship, since once calibrated, the mass could be obtained by measuring the luminosity of any galaxy! However, measured in units of the sun's mass and luminosity, the value of the constant of proportionality (the mean mass-to-light ratio, M/L) for different types of galaxies is still questioned.

There are two additional methods of measuring the masses of individual galaxies. Both involve studying the internal motions of the stars and gas within the galaxies. Both methods are subject to the same criticism; they only provide information about the mass of the galaxy which lies interior to the outermost measurement point.

The first method is usually applied to spherical elliptical galaxies or the nuclei of spiral galaxies. In this method, the *velocity dispersion* of the stars moving in the gravitational field of the galaxy may be used to estimate the galactic mass. The dynamical mass estimate is based on the Virial theorem (see the accompanying box) which is fundamentally important. Knowing the stellar masses and measuring their line-of-sight velocities and apparent distances from the galactic center produces a good approximation to the total kinetic energy and the shape of the potential energy distribution of the galaxy. Once these are known, the only unknown is the total gravitational mass holding the system together. Mass estimates derived in this way are often called *Virial masses*. Mass-to-light ratios for elliptical galaxies obtained in this manner agree with Page's result.

The second method works for rotating galaxies containing hydrogen, such as spirals. The velocity of rotation at any distance from the galaxy center can be measured optically or by 21cm radio emission from neutral hydrogen. At large distances from the galactic center the resulting rotation curve (a plot of rotation velocity against distance from the center of the galaxy) looks very much like one of stars and gas moving in circular Keplerian orbits. Thus the mass interior to any radius can be readily deduced.

However, radio astronomers have recently upset the applecart! In 1973, Drs. Morton Roberts and Arnold Rots of the National Radio Astronomy Observatory detected neutral hydrogen gas extending far beyond the optical images of some nearby spiral galaxies. Moreover, the rotation curve they measured did not drop down at the optical edge of the galaxies, but continued to remain roughly flat even out to these large distances. The measured mass of the galaxy seems to continue to grow greater with distance from the center, even though the starlight is decreasing rapidly! This discovery has led to the *massive halo hypothesis* for spiral galaxies — the latest of the missing mass problems. For now, let's return to the missing mass problem first discovered — that in clusters of galaxies.

The Virial Theorem: Key to Cluster Masses

The Virial theorem allows astronomers to make the giant leap from a list of radial velocities and positions in a star cluster or cluster of galaxies to the total mass of the system. Provided certain conditions are met, if a large number of objects (stars for example) are bound together by their mutual gravitational attraction, they will move about one another in such a way that the total kinetic energy of all the individual motions is equal to half the potential energy of the system (which depends only on the *total* mass and spatial distribution of the objects). Knowing the stellar masses and measuring their line-of-sight velocities and distances from the star cluster center produces a good approximation to the total kinetic energy and the shape of the potential energy distribution. The only unknown is the total gravitational mass holding the system together.

Astronomers take great care that the conditions are met. Has the cluster existed long enough to allow the stars (or galaxies) to reach an equilibrium or become dynamically relaxed? Is the system truly isolated, or are other significant forces acting on it? Astronomers are generally satisfied that these conditions are fulfilled: The virial masses can't be explained away easily.

Galaxies frequently occur in clumps, ranging from groups with a few members to rich clusters having many thousands of members. These groupings are easily recognized and appear to be isolated, well behaved, gravitationally bound configurations — made to order for astronomers to apply the Virial theorem! In fact, as soon as sufficient radial velocity measurements of galaxies in groups and clusters were available, this was done. The results were startling. The masses of the clusters predicted by the Virial theorem were 10 to 500 times the cluster masses estimated by adding up the masses of the individual galaxies. The situation was so disturbing and unexpected that a special conference was convened in Santa Barbara in 1961 to attempt to resolve the problem. Either galaxies in clusters were *much heavier* than the nearby galaxies which had been studied, the local mass-to-luminosity determinations were incorrect, the clusters themselves were not gravitationally bound together but exploding apart (and thus not suited to Virial theorem analysis), or something existed unseen within the clusters to provide the mass necessary to bind them together. Astronomers at the Santa Barbara symposium were unable to resolve the problem.

Since then, new observations have been made which rule out one after another of the more obvious solutions to the missing mass problem. At the same time, the conviction that the rich clusters of galaxies are indeed gravitationally bound has grown. Fortunately, some of the small groups of galaxies in which the most extreme mass discrepancies arose have been recognized to be chance superpositions on the sky of galaxies which are not physically associated. Nevertheless, the general problem refuses to go away: Somewhere, somehow, rich clusters of galaxies contain 10 times more mass than expected.

Where could all that missing mass be? It isn't hiding in the spirals — even if they are more massive than previously thought — because rich clusters contain few spiral galaxies. Suppose *all* galaxies are 10 times more massive than we thought. If this *is* the answer to the missing mass problem, then the additional galactic mass must be far from the centers of the galaxies (at large distances, compared with the optical galaxy size). If this weren't so, then over the 10 billion year lifetime of the rich clusters, near collisions between the galaxies would have been very effective in rearranging the galaxy orbits. Faint low mass galaxies would have been speeded up and moved toward the outer edges of the clusters, while the more massive galaxies would have slowed down and sunk to the center of the cluster. Such mass segregation is not observed in the clusters, so we conclude that if the missing mass is associated with the galaxies themselves, it must be in the form of extended halos about each galaxy. If the extended halos are extended *enough*,they become equivalent to a diffuse intergalactic/intracluster medium. The logical next question is, *what form of matter could exist unseen between the galaxies*?

There is some gas spread throughout the clusters, but not enough to account for all the missing mass. This gas is very hot — about 100 million degrees Kelvin (as it must be to support itself against the gravitational field of the cluster), and it can be observed because it emits x-rays (see "The X-Ray Universe", July 1977).

Another possibility is that cooler gas could also exist *between* the galaxies if it were clumped into clouds that orbit the cluster center as the galaxies do. If these gas clouds were neutral, they could be expected to contain atomic hydrogen, which emits line radiation at 21cm, like the interstellar clouds of the Milky Way. If the gas clouds were ionized, they would emit line and continuum radiation at optical and radio wavelengths. Careful searches for the anticipated emission have been carried out at many frequencies without success. The missing mass does not appear to exist in the form of cool intracluster gas. Neither can it be present in the form of dust grains, because the clusters of galaxies do not strongly obscure background objects. Nor can the missing mass be in the form of ordinary individual stars swarming about between the galaxies. The number of stars required to supply the missing mass is so large that the total light from even the faintest type stars would have already been detected by the sensitive searches that have been performed.

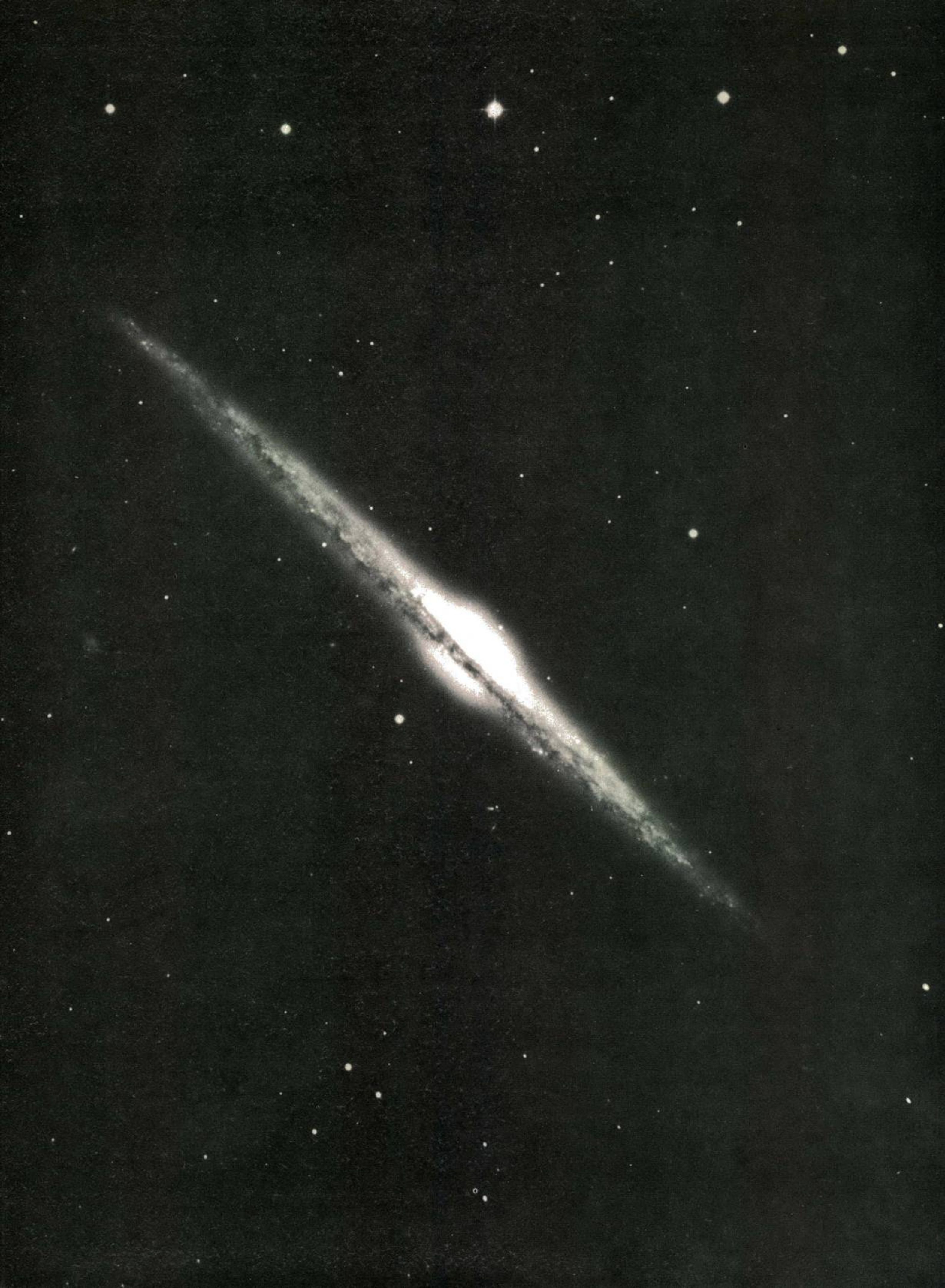
However, it is possible that a type of "almost star" could provide the missing mass and still remain successfully hidden. This type of object is called a *brown dwarf*. Ordinary stars are born when clouds of gas contract gravitationally until the density and temperature at their centers become great enough to fuse hydrogen into helium. If the mass of the gas cloud is less than 0.08 times the mass of our sun, the temperature at the center of the cloud will never get hot enough to start the hydrogen fusion reactions working and "turn on" a star. A brown dwarf is just a star which isn't massive enough to shine by nuclear burning. A brown dwarf emits some light for a short time as it radiates away the excess heat of contraction. Eventually it ends up as a bigger version of Jupiter (whose mass is 0.001 times that of the sun).

Why might we expect brown dwarfs to exist at all? For every solar mass star that is formed, many low mass dwarf stars also form. Perhaps very many more still lower mass brown dwarfs form as well. These may have escaped from the galaxies to fill the intracluster medium, and thus remain undetected even though there must be at least 10^{17} of them to account for the missing mass. The major difficulty with this solution to the missing mass problem is that no one has ever seen a brown dwarf! Their existence has not been verified, although it should be possible to find them with the new infrared telescopes planned for space in the next decade.

There is another type of unseen and unseeable object predicted theoretically, which could also explain cluster mass discrepancies: the black hole. A black hole results whenever matter contracts to such extremely high densities that the local gravitational field becomes strong enough to recapture any photons emitted, preventing any light from escaping. Black holes are therefore invisible. They may come in a wide range of sizes from supermassive holes (which Sir Fred Hoyle believes are the best model for quasars) down to tiny holes, whose masses are an infinitesimal fraction of a gram and whose sizes are limited by the discontinuities in spacetime itself.

The cluster mass problems can not be resolved by postulating a few large black holes near the clus-

NGC-4565, the edge-on spiral in Coma Berenices, is surrounded by a massive halo of stars that may account for a substantial amount of its missing mass. The halo, detected by Dennis Hegyi and Garth Gerber of the University of Michigan, appears to be composed of billions of cool, low mass stars — perhaps having enough mass to account for the rotation curve observed by radio astronomers. Despite its mass, the halo is so faint that it cannot be photographed directly. The discovering astronomers used a special scanning photometer to measure its extent. This discovery was further described in Astro-News, February 1978. Hale Observatories photograph.



ter center. They would have torn apart — or at least strongly distorted — galaxies passing nearby, and the cluster galaxies appear unperturbed. However, the primordial black holes proposed by Dr. Stephen Hawking, which have masses $\gtrsim 10^{15}$ grams (approximately the mass of a small mountain) and dimensions on the order of a proton (see "Miniblack Holes", ASTRONOMY, February 1977), offer a possible solution. The miniblack holes do not violate any observed features of clusters of galaxies. The age at which they will explosively evaporate (making their presence known) exceeds the current ages of the rich clusters. In addition, their occurrence within the clusters is quite plausible. Miniblack holes are believed to have formed from small scale, large amplitude density perturbations in the early universe. They would have naturally been included inside the large scale, small amplitude density perturbations in the primordial fireball, which eventually condensed into clusters of galaxies.

Binding clusters of galaxies with brown dwarfs does not significantly change the current estimate of the mean mass density in the universe, while resorting to primordial black holes does. Brown dwarfs will have formed only in those regions of space currently occupied by galaxies, but primordial black holes could fill the space between the galaxy clusters as well.

There was a third choice for the binding agent mentioned above — massive galaxies with extended halos. Although the radio observations of nearby spiral galaxies (already mentioned) tend to support this concept, in fact there really is no third choice: Massive halos are another missing mass problem! Just as in the case of star clusters, additional radio, infrared and optical observations have ruled out "conventional" forms of matter as the primary halo constituents. Dr. Hyron Spinrad of the University of California at Berkeley and others have discovered diffuse emission at long optical wavelengths far from the main bodies of several galaxies. This emission, which appears to be ordinary starlight, is too faint and decreases too rapidly away from the galaxy to account for the halo mass implied by the 21cm neutral hydrogen rotation curves. High velocity neutral hydrogen clouds at great distances from the centers, apparently associated with several galaxies, have also been detected. But again, the amount of mass involved is insufficient to account for a massive halo.

Thus, it appears that to supply the missing mass of the massive halo, brown dwarfs and/or primordial black holes are required. Both possibilities pose problems however. Primordial black holes may be more plausible because they would be expected to be part of any density perturbation which became a protogalactic cloud and later a galaxy — and they may have been able to remain an extended swarm surrounding the final galaxy. For brown dwarfs to be arranged in a large spherical halo requires that star formation start very early in the low density era of the protogalaxy and produce primarily small stars. However, theoretical arguments by Dr. Joseph Silk of the University of California imply that the first generation of stars to form in any galaxy are likely to be very massive. For now, the odds on either form of missing mass are about equal.

Brown dwarfs and miniblack holes may be useful to explain another minor mass discrepancy in our own backyard, the local solar neighborhood. In 1965, Dr. J.H. Oort of Sterrewacht, Leiden, pointed out that the total mass observed in the form of stars, gas and dust in the galactic plane was insufficient to account for the motions of the K and M giant stars above the plane of the galaxy. Brown dwarfs formed at the same time as the visible stars provide a natural solution to this missing mass problem. Even though there may be as many as 10 of these objects between the sun and the nearest stars, they would have gone undetected so far. They will be visible (if at all) only as faint red "stars" with large proper motions — so faint that they would have been beyond the magnitude limits of the infrared and optical searches already completed.

It is exciting to contemplate the discovery of these theoretically predicted bodies by space borne instruments. It could become the major "find" of the next decade! And what if brown dwarfs in large numbers are not detected? There are always primordial black holes, perhaps even several within the solar system itself. Since miniblack holes become observable only in the last instants of their lifetime, it is unlikely that astronomers can ever verify the existence of an individual primordial black hole. Their reality and number density may be inferred and accepted only when, and if, no other possible explanation can be found for the galactic gamma ray background at energies around one Giga electron volt.

In this article, we have considered several worrisome mass discrepancies associated with objects of decreasing physical size. Drs. Jeremiah Ostriker, P.J.E. Peebles and Amos Yahil of Princeton University have reversed this perspective and revised an old astronomical hypothesis. They have drawn attention to the fact that as the length scale over which masses are measured increases — from the distance between binary galaxies to the dimensions of a cluster of galaxies — so too does the apparent mass discrepancy increase! Perhaps this phenomenon continues up to a length scale characteristic of the universe itself! If this old/new idea is correct, then the primordial black holes will provide the elegant — and self-consistent — solution to missing mass problems over all length scales.

Jill Tarter works at NASA's Ames Research Center in California. Her previous work has been in theoretical astrophysics, studying clusters of galaxies and the x-rays that come from them. Currently she is involved in the search for extraterrestrial intelligence, analyzing radio telescope data for beaconlike radio signals.

Celestron® Telescopes... Telephoto Lenses... Binoculars...

C90

At last! A quality telescope designed with the beginner in mind and priced so that he can afford it. It's the Celestron 90 and with it you'll be able to study lunar craters, the rings of Saturn, the cloud belts and moons of Jupiter, and scores of nebulae and galaxies. During the day you'll see bees buzzing in flowers 20 feet away, observe birds feeding their young in nests 50 feet away, identify airliners miles away, and much more.

Versatility: The C90 is much more than just a quality astronomical telescope. It's also the ideal telescope for birdwatching, wildlife/nature viewing, or general spotting.

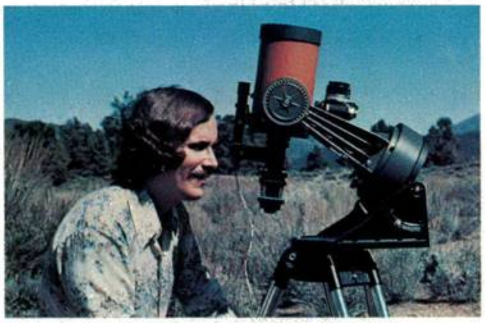
The Celestron 90 has the same quality and features that have made Celestron telescopes world famous:

Available as a telescope, telephoto lens, or spotting scope.

750mm f/6 or 1250mm f/10

For the larger aperature photographer we offer two photo versions of the Celestron Telescope: a 750mm, f/6 and a 1250mm, f/10. Each is less than a foot long, tips the scales at four pounds and attaches instantly to your 35mm SLR or C-mount movie camera.

Unlike most other mirror-lens telephotos, the 750mm or the 1250mm can be used as a telescope for daytime observing or for stargazing, at powers up to 300X.



C5

While there is no substitute for the brilliance, detail and clarity of image offered by a well-made, optically large telescope, extreme portability is sometimes as much a factor in selecting a telescope as is larger-aperture performance. The Celestron 5 offers extreme portability at an aperture large enough for serious astronomical observing and photography.

Weighing in at a mere 13 pounds, this 300-power telescope is as portable as your briefcase and as easy to use. It is also a remarkably versatile telescope—being a daytime telescope, a 25X telephoto lens, an astronomical tabletop observatory and a deep-space camera all in one instrument. This is the ideal telescope for nature enthusiasts, telephotographers and amateur astronomers.

C8

When the Celestron 8 was first introduced, it caused more than a slight stir among serious amateur astronomers, astrophotographers and astronomy educators. Here, at last, was a large-aperture telescope designed for a modern age: it was really portable, easy-to-use and incredibly versatile. Today, the Celestron 8 is the world's best-selling 8-inch telescope.

Though it tips the scales at only 21 pounds and takes up less room than a suitcase, this 480X telescope more than delivers the optical performance so essential to the serious amateur or research scientist. And not only is the C8 the superior astronomical instrument its reputation suggests, it is also the ultimate daytime telescope and 40X telephoto lens.

C14

Revolutionary in concept and design, the Celestron 14 for the first time makes truly portable a telescope with aperture approaching professional size. This is the world's largest one-man-portable observatory telescope.

As an astronomical telescope, the Celestron 14, with 2,580 times the light-gathering power of the human eye, is a superior instrument indeed—whether for lunar, planetary, or deep-sky observations. And the prestige of the instrument is enhanced by such amenities as a control panel and electrical slow-motions in both axes.

Celestron International 2835 Columbia St., Box 3578B, Torrance, California 90503. Telephone (213) 328-9560

The Celestron Telescope

The optical quality of Celestron Telescopes is famous the world over. These telescopes are selected repeatedly by professional educators, amateur astronomers and research scientists, as well as by casual observers and photographers throughout the world.

Attractively modern, Celestron Telescopes are superbly crafted for the discriminating telescope enthusiast. And they are worlds apart in performance, reliability and versatility.

Celestron Telescopes feature large optics, and employ lenses and mirrors to optically fold long high-power focal lengths into a compact configuration. The result is observatory-size optics portably packaged.

Because these telescopes are of large aperture, their images are bright and detailed. Even at high power, the clarity, brilliance and detail of the images will astonish you.

By day, the Celestron is superb for long-distance macroscopy, nature studies, sports action and candids. You can bring into sharp focus the antennae of a butterfly at 15 feet, or the face of a friend at half a mile.

At night under adverse city light conditions you can study the Moon and planets from your backyard—exploring lunar craters and rills. You can observe the Moonlike phases of Venus, the surface features of Mars, the cloud belts of Jupiter, or the rings of Saturn.

Under dark skies, you will have at your fingertips the vast star clouds of the Milky Way, hundreds of globular and galactic star clusters, scores of diffuse and planetary nebulae, and galaxies millions of light-years away.

At more than a thousand colleges and universities throughout the world, Celestron Telescopes are adding a new dimension to astronomy education—for the first time giving students access to large, modern, deep-space telescopes and the projects they make possible.

And at science centers around the world, these instruments are finding numerous research and industrial applications in such fields as laser communication, solar energy, satellite tracking, high-altitude atmospheric monitoring and pollution control.

These are truly scientific instruments, at popular prices.

Rest the Celestron anywhere, swing up its tube and it's ready for casual observing or scanning the night sky. The Celestron is the ultimate in operational simplicity.

With its sturdy fork mount, its slow-motion controls for fine adjustments in telescope point, and its instant-lock clamps, aiming the instrument is as easy as pointing your finger.

But the Celestron is more than a telescope. It is also part of a fully integrated system of photovisual instruments and accessories—the most extensive such system ever offered.

The capability of the Celestron system ranges from casual nature studies to advanced telephotography, and from astronomical observing to professional deep-sky photography.

So the basic features of Celestron Telescopes and the capability of the Celestron system make these the most versatile telescopes available. And they also make the Celestron a telescope that grows with your interests.

For instance, convenient photographic adaptors for terrestrial, planetary or deep-sky photography couple your 35mm SLR camera body to the telescope instantly. And the tube assembly demounts readily from its fork mount for telephotography on photo tripod.

By adding other accessories to the Celestron, you can expand it into a research instrument or into an astrophotographic laboratory. And your photographs will rival in aesthetic quality those produced at the major professional observatories.

This is the Celestron. It is what every telescope should have been in the past. It may well be what every telescope will be in the future.

Basic Specifications

Feature	(astro) C90	750mm telephoto	1250mm telephoto	C5	C8	C14
Optical Configuration	Maksutov	Schmidt	Schmidt	Schmidt	Schmidt	Schmidt
Clear Aperature	3.55″	5″	5″	5″	8″	14″
Effective Focal Length	1000mm	750mm	1250mm	1250mm	2000mm	3900mm
Photographic Speed	f/11	f/6	f/10	f/10	f/10	f/11
Ocular Included	Yes[1]	No	No	Yes[2]	Yes[2]	Yes[4]
Near Focus—Approx.	10′	15′	20′	20′	25′	100′
Resolution						
Arc Seconds	1.3°	0.9°	0.9°	0.9°	0.5°	0.3°
Lines per mm	120 LPM	333 LPM	200 LPM	200 LPM	210 LPM	171 LPM
Image Scale	1.43°/in.	1.1°/in.	1.12°/in.	1.12°/in.	.72°/in.	.37°/in.
Coverage	35mm	35mm	35mm	35mm	35mm	2¼x2¼
Weight	8 lbs.	4 lbs.	4 lbs.	13 lbs.	21 lbs.	108 lbs.
Size/swingdown	7″x7″x13″	5.5″x10″	5.5″x11″	7″x8″x16″	9″x12″x22″	18″x22″x44″
Construction	All Aluminum					

More Information

For complete data on all our products and to enjoy many beautiful photos, order our thirty-two page catalog—$2.00.

In addition to the 32 page catalog, we also offer detailed instruction booklets.

750/1250 Telephotos—$1.00
C5/C8 Telescope—$1.00
C14 Telescope—$1.00
Schmidt Camera—$1.00

Accessories:

Celestron offers the most complete line of accessories of any telescope manufacturer. Below are listed a few of the items.

Equatorial Wedge

For the electric drive and the setting circles of the Celestron Telescope to operate properly, the base of the telescope must be tilted up to an angle corresponding to your geographical latitude so that the polar axis of the telescope parallels the axis of rotation of the Earth. The Equatorial Wedge Assembly accomplishes this and is available in a model for our C5 or C8, and in a model for our C14. The equatorial wedge is constructed of heavy-duty cast aluminum. The C5/C8 wedge weighs 5 lbs. and the C14 wedge weighs 30 lbs. Both provide for fine adjustments along the vertical.

Basic Photography

35mm camera couples to the Celestron using T-Adaptor and T-Ring.

One of the most exciting features of the Celestron is just how easy it makes high-power photography. Simply couple a few accessories to the telescope and in seconds you're ready to photograph a hummingbird at 20 feet, or the rings of Saturn. With the Celestron, telephotography is a snap—as is lunar, solar or planetary photography—and with experience, dramatic nature shots or candids are more the rule than the exception.

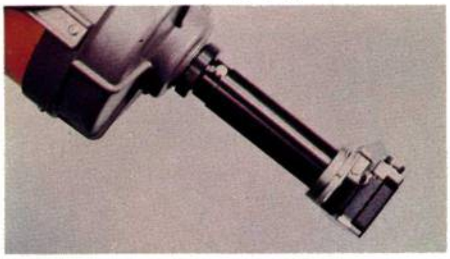
Still Photography

For still photography with your 35mm single-lens-reflex camera body, all that is required is our T-Mount Camera Adaptor and a T-Ring for your specific camera. (We offer camera rings for most 35mm SLR's. See our price list. Other T-rings can be obtained through your photo dealer.) The T-Adaptor couples the camera body to the rear-cell of the telescope by way of the T-ring, and permits the camera body to be oriented in either a vertical or a horizontal format.

Locked Triangle Tripod

Designed for use with our equatorial wedge (see above), the Locked-Triangle Tripod is exceptionally sturdy, easy-to-use and portable. It is available in two models: one for the C5 or C8, and one for the C14. The C5/C8 tripod weighs 10 lbs. and, when set up, stands 37 inches tall. The C14 tripod weighs 30 lbs and stands 35 inches tall. The C5/C8 tripod accepts either telescope directly (without the wedge) for daytime alt-azimuth observing.

Lunar and Planetary Photography

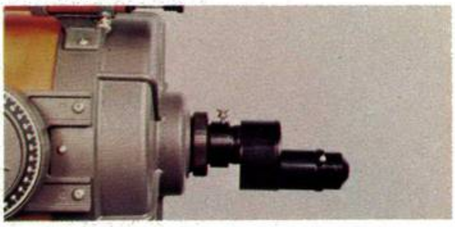


Tele-Extender, eyepiece projection, used for planetary photography to greatly increase image size

For close-up lunar or solar photography, or for planetary photography, the T-Mount Camera Adaptor is replaced with our Tele-Extender tube and visual back with an ocular used to project a magnified image to the film plane. You can select the amount of magnification that you desire by the focal length of the ocular that you use. The 40mm ocular increases the image size by 3.4 times. The 25mm, 18mm, and 12mm oculars increase the image size by 6, 8.7, and 13.6 times respectively. There is nothing gained by using shorter focal length oculars in the tele-extender as the diffraction limit of the telescope would be exceeded.

Our general 32 page catalog has a description of many accessories not listed here.

Porro Prism

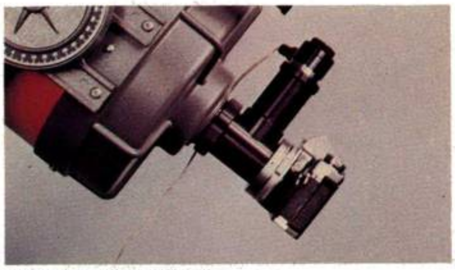


Porro Prism used with Celestron 8 for straight through erect image viewing.

For daytime observers who desire straight-through viewing with erect images with correct left to right orientation, we offer the Porro Prism. A 24.5mm barrel diameter unit for our 5 inch instruments, and in a 1¼″ barrel diameter for our C8 and C14. (An ocular inserted directly into the Visual Back of the Celestron produces images that are upside down and backwards). The star diagonal supplied with the telescope turns the image right side up but does not correct it right for left.

Guided Photography

Making time exposures of deep-sky objects requires "guiding," a process whereby the astro-photographer makes fine adjustments in telescope point during the course of the exposure. Guiding is necessary because even with an electric drive there is very slight movement of the image in the field of view, and this movement cannot be tolerated on film. To guide the Celestron, we offer our AC-DC Drive Corrector and Off-Axis Guider.



Off-Axis Guider on the C8

Drive Corrector

Celestron Binoculars

The Why and How... Celestron through its dedication to high resolution astronomical quality optical systems has become the most coveted optical instrument among the professionals and serious amateur star gazers.

In establishing a specification for a low-light level binocular, we established specifications that were beyond those of the garden-variety which are popularly offered. A low-light level night time binocular suitable for viewing star clusters and faint nebulae. The images must be crisp and free from color distortion. For maximum image brightness, the exit pupil of the binocular must as closely as possible match the dark adapted entry pupil of the observer's eye.

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750mm f/6 Inset comparison shot taken with 50mm lens— same enlargement.

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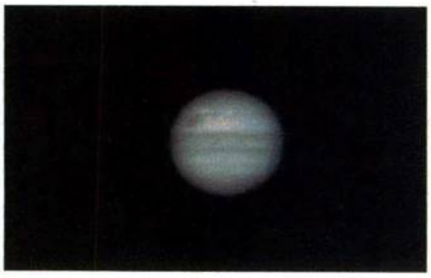
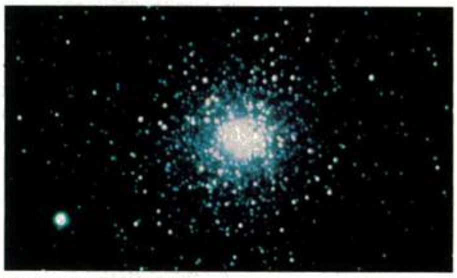

C8 Jupiter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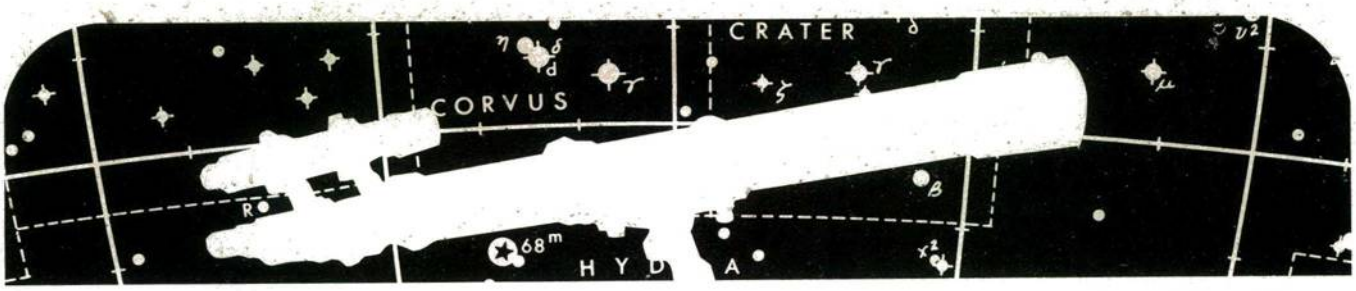


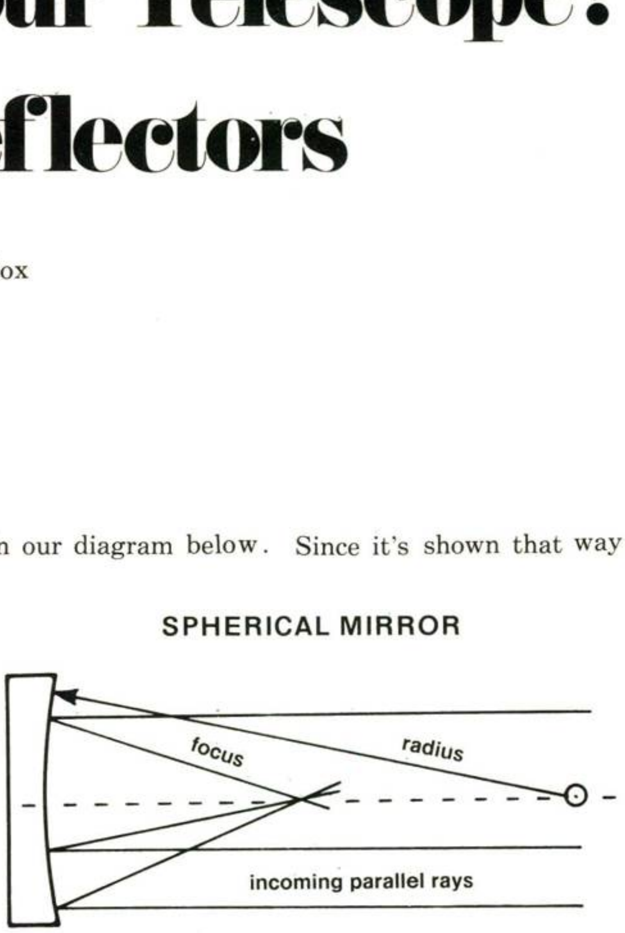
What's Inside Your Telescope? Part 2: Reflectors

by
Robert E. Cox

The most popular telescope used by hobbyists and professional astronomers is the type called *catoptric*. What is a catoptric telescope? As the magician often remarks about his illusions, "It's all done with mirrors!" So it is with a catoptric telescope: It uses mirrors — rather than lenses — to form its image. The magician's remarks are most appropriate especially to those who grind, polish and figure their own telescope mirrors, and then enjoy the magic of astronomy through the eyepiece of the finished instrument.

The principle of image formation by a concave spherical surface is quite simple. Parallel light — perhaps from a star — striking it will converge to a focus at a point *halfway* between the center of curvature of the mirror and the mirror center, as shown in our diagram below. Since it's shown that way in the drawing, are the surfaces of a reflecting telescope mirror spherical in shape? Unfortunately, they aren't. The drawing is a simplification of the principle. On close examination of the image forming qualities of spherical surfaces, you'll find that the edge rays meet the optical axis just a bit closer to the mirror than those from the central area. This problem is called *spherical aberration*. The deeper the sphere is, the worse the aberration becomes. But by making the focal length of a spherical mirror very long, the aberration becomes so small it no longer matters. Indeed, a long focus is the same solution applied to simple lenses to secure a satisfactory image. If all other optical parts of the instrument are perfect, you can

SPHERICAL MIRROR

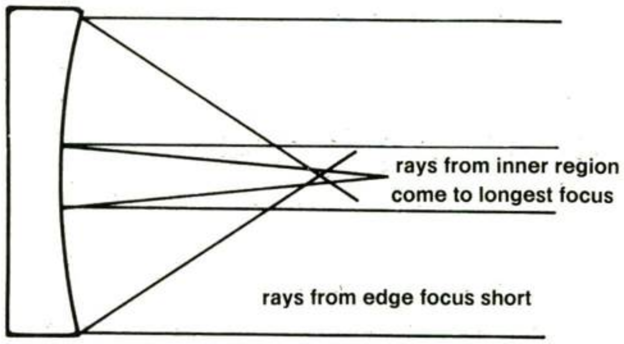


When Is A Sphere Good Enough?

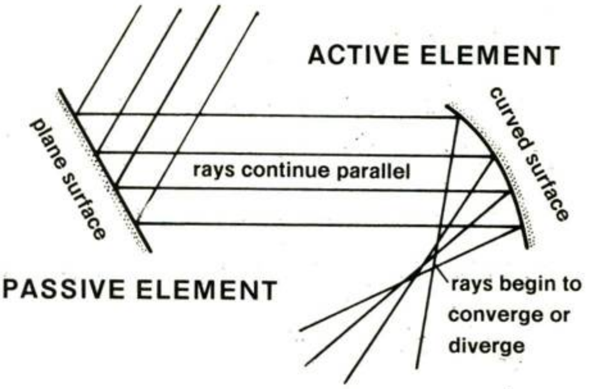
Aperture	Focal length good to 1/4 wave	Focal length good to 1/8 wave
4-1/4 inch	34 inch	42 inch
6 inch	50 inch	62 inch
8 inch	72 inch	91 inch
10 inch	97 inch	123 inch
12-1/2 inch	131 inch	165 inch

use a spherical mirror perfectly well if it has the focal lengths shown in the table. Since the other optical components are not perfect, the focal length listed as "1/8 wave" is the recommended focal length. A spherical mirror six inch telescope is probably the largest practical size for the average observer in terms of handling and storage.

SPHERICAL ABERRATION



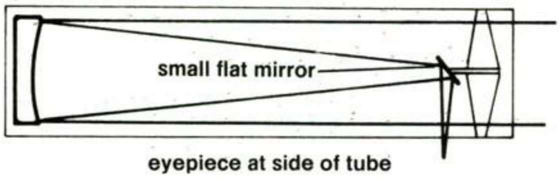
In describing the optical parts of catoptric instruments, the terminology used with lens optics is valid. Thus, optical parts that have curved surfaces and contribute to the actual formation of the image are called *active* elements, and those that do not contribute are *passive*. The primary mirror is obviously an active element in this system.



The most popular and simplest telescope using a concave collecting mirror is one proposed by the famous astronomer, mathematician, physicist and optician, Sir Isaac Newton. Newton built a model of the first "Newtonian" in 1668, but the first large aperture working instrument of this design was built by John Hadley in 1721. It had an aperture of six inches and a focal length of 62 inches. (Its focal length was such that it fits into the recommendation for a spherical figure found in the table accompanying this article.)

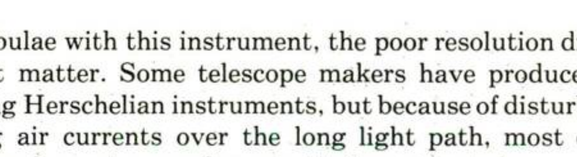
In order to permit an observer to see the image in his reflecting telescope, Newton placed a small passive element in the converging light cone to direct it to the side of the tube where it could be conveniently observed. It is immediately apparent that the small flat mirror obstructs some light from the object. The size of the diagonal mirror that directs the light to the side should be kept as small as practical for the type of observations intended, but generally should not exceed 30 percent of the aperture.

NEWTONIAN



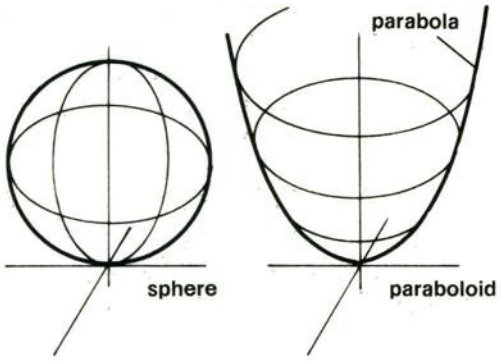
"Can't I just tilt the mirror to direct the converging light cone to one side so there won't be any obstruction in the instrument?" you might ask. Sir William Herschel, the famous English astronomer and instrument maker, did exactly that with his telescopes! To allow for the errors, or aberrations, such a tilt introduced, the focal length has to be made much longer: For a four inch mirror, it should be about 95 inches; for a 6-1/4 inch mirror, 170 inches, and for an eight inch mirror, 250 inches. Herschel did not use the correct focal length on his mirrors and his biggest telescope — a 48 inch reflector with a 480 inch focal length — and consequently had the resolution of only a two inch instrument! Since he observed nebulae with this instrument, the poor resolution did not matter. Some telescope makers have produced long Herschelian instruments, but because of disturbing air currents over the long light path, most of them haven't proved as practical as expected.

HERSCHELIAN TELESCOPE



Most reflecting telescope — either homemade or those sold commercially — have shorter focal lengths than those listed in the table. How do they overcome the aberrations caused by the spherical surface figure? Obviously, you'd have to make the mirror with a figure other than spherical! In the majority of catoptric telescopes, the figure is that of a *paraboloid of revolution*. The paraboloid is a conic figure that has the property that all light parallel to its axis reflects to a common focal point. In the case of the mirrors listed in the table, the depth difference between a spherical surface and one with the paraboloid is measured in wavelengths or fractions of wavelengths of light — millionths of an inch! In the common six inch f/8, the difference amounts to about 11.4 millionths (.0000114) inch.

"PARABOLIC" MIRRORS



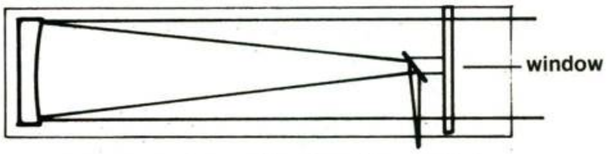
In a Newtonian optical system, light enters at the top of a supporting tube and strikes the concave surface of the primary mirror at the bottom. This reflects the light toward a focal point at the top of the tube. But before reaching focus, it is intercepted by a flat diagonal mirror and reflected out the side of the tube to the eyepiece (see the drawing on page 32). The diagonal mirror is a passive element in the system, but this doesn't mean that it doesn't contribute to the imaging properties of the telescope. The quality (or figure) of its surface is not important. The quality of a Newtonian telescope is controlled by the figures of both optical elements. If the primary is accurate to 1/16 wave of green light and the flat is equally good, the resultant accuracy of the two is 1/8 wave! Thus, although the diagonal is flat to within 1.4 millionths inch, it still, in combination with the primary, degrades the final image quality. The combined 1/8 wave error by the surfaces results, however, in an image that is still passably good. Optical theory developed by Lord Rayleigh in 1878 states that if all the light reaching a focus doesn't vary in its errors by more than 1/4 wavelength, then the image quality won't fall seriously short of the performance possible with a perfect system. The combination of mirrors in our example is better than 1/4 wave, and therefore performs quite well.

Some kind of supporting structure is needed to hold the diagonal mirror centrally over the primary mirror at its location near the top of the main tube. This device is usually called a spider. Some sort of strut type structure is normally used, the most common having four vanes. A small amount of light is obstructed by the vanes, but a much more serious problem arises from having it in the light beam. Light is scattered, or *diffracted*, from it causing spikes to appear on bright starlight objects. Such spikes aren't only distracting, but they can hide the separation of a double star if one star happens to fall on one of the spikes.

The spider needn't have straight legs. A number of curved vane spiders have been proposed and used. They don't eliminate the scattered light caused by the vanes, but they do scatter it around the field in a uniform manner so that you aren't conscious of the diffraction spikes when viewing bright objects. However, there is some degradation in the image quality caused by the scattered light which — although not visible as spikes — does affect faint and low contrast details in planetary observations.

The most obvious solution is to eliminate the vanes and to mount the diagonal on a glass *window* at the front of the tube. The window is a passive element (being a piece of glass with flat and parallel surfaces), but its surface accuracy and parellelism do affect the quality of the final image. If the window isn't coated with an *antireflection* coating, you may be bothered by ghost images of bright objects located off the center of the field. For low power applications with a small instrument, you can just place a large sheet of glass in front of the telescope while observing a bright star. If you can find an area in which image degradation isn't noticeable, cut it out and use it for the window. This method works well on low power richest field telescopes.

A WINDOW TO THE SKY

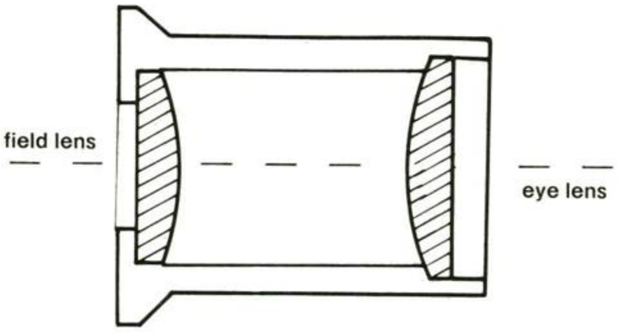


window must be quality glass, flat, parallel

For narrow field and high power use, it's necessary to be more critical in the quality of the window. It might be necessary for you to actually grind, polish and figure a special piece of window glass. With sufficient care and skill, excellent performance — plus freedom from air currents and diffraction spikes — could be yours!

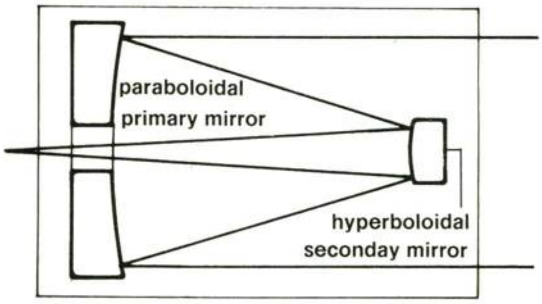
As in all visual telescopes, the image formed by the objective, whether it be mirror or lens, is examined by an eyepiece to present the final enlarged picture to the observer's eye. The simple Huygens eyepiece, or ocular, designed for refractors (dioptric instruments) is not usually satisfactory when used on a catoptric telescope. Around 1768, Jesse Ramsden developed an eyepiece to provide better correction for use on the reflecting telescope. He also placed the *image plane* outside the first lens so it could be used with a crosshair or used to read graduated circles. In a Ramsden eyepiece, the two plane surfaces of the lenses in the ocular face toward the incoming light (see the drawing below); in the Hygens, both convex surfaces face toward the incoming light.

RAMSDEN EYEPIECE



There are important forms of catoptric telescopes other than the Newtonian. In them, more than one mirror have an active function in the formation of the image. The most widely known and used are those called *Cassegrains*. The basic design was revealed by a Frenchman named Cassegrain in 1672, just a few years after Newton demonstrated his telescope. The primary mirror — like the Newtonian — is a parboloidal surface. In the center of the mirror, however, is a hole, while close to the focus of the large mirror — but inside it — a small convex mirror returns the light *through* the hole in the primary to a final focus (see the drawing below). Neither mirror is spherical — both are *aspheric*. The secondary mirror is hyperboloidal in classic Cassegrain telescopes; it acts, in principle, as a Barlow lens. The distance from the convex mirror to the final focus, divided by the distance it has been placed inside the focus of the primary mirror, is its amplifying factor. Large observatory telescopes are all designed to operate as Cassegrain instruments even when they have a Newtonian focus position. The advantage of the Cassegrainian telescope is that it has a short tube, reducing the cost of the mounting and the size of the expensive observatory dome.

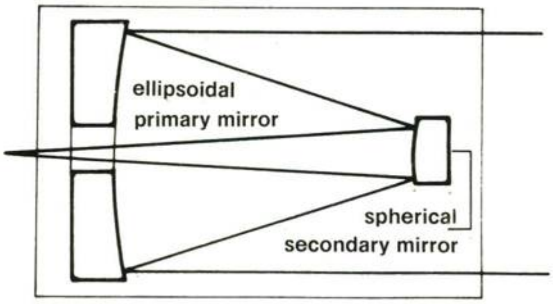
CLASSICAL CASSEGRAIN



A simplified form of Cassegrain was invented by two amateur telescope makers, Alan Kirkham of Tacoma, Wash. (who is deceased), and Horace E. Dall, an Englishman who is still active in optics. The simplification — devised independently by these two gentlemen — was to make the primary mirror an *ellipsoid*, a conic curve between a sphere and a parabola, which — having less correction — was easier to make than a parabola. But the real advantage is that the figure on the convex secondary becomes spherical, and spherical surfaces are easier and cheaper to manufacture than any other surface — including flat or plane surfaces.

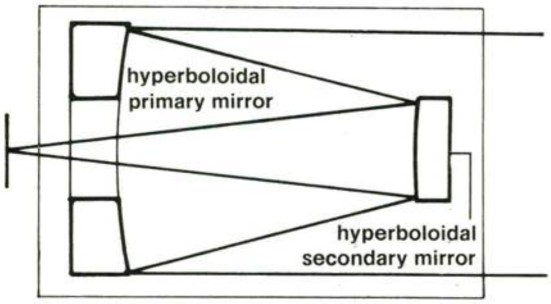
The Dall-Kirkham Cassegrain, as it's known, is widely used by telescope makers who want to obtain the advantages of a Cassegrain without too much difficulty in fabrication. Although both classical and "D-K" are about perfect on the optical axis if the optics are perfectly made, the images at the *edges* of the field of the Dall-Kirkham are inferior to those in the classical Cassegrainian instrument. Since astronomy enthusiasts do not demand the perfection of a professional telescope at the edge of the field, the Dall-Kirkham is a good type of telescope for you to make. As has been often stated by serious observers, "The edge of the field of view is for acquisition; for serious viewing, you place the object on the axis and in the center of the field of view!"

DALL-KIRKHAM CASSEGRAIN



The most popular Cassegrainian type telescope used by professionals in astronomical work is a two mirror system in which both optical figures have a hyperboloidal surface. The design was developed by American telescope maker George W. Ritchey, and French optician Henri Chrétien. Ritchey-Chrétien

RITCHEY-CHRÉTIEN CASSEGRAIN

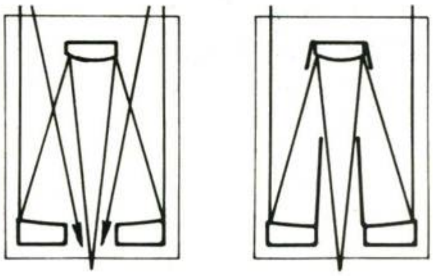


Cassegrains correct the off-axis errors of the classical Cassegrainian, permitting a wider field valuable for photography. Where the classical Cassegrain used by professionals often had a final focal plane distance of 15 to 25 times the primary mirror diameter (f/15 to f/25), the Ritchey-Chrétien operates well with a distance of only seven times (f/7). As a consequence, its photographic speed is more than four times greater than the Cassegrainian with a parabolic-hyperbolic set of mirrors.

The Ritchey-Chrétien has one troublesome error: Its focal plane may be curved toward the incoming light. In order to use the instrument, the photographic plates must be bent during exposure to the correct curvature in order to take advantage of its otherwise excellent definition. In the modern form of this design (used on all large American catoptric telescopes built since World War II), the field is made flat either by a series of special lenses placed close to the final focal plane or by careful choice of mirror radii to yield a flat focal plane.

A serious problem with all compound catoptric instruments is *sky flooding*. Light from the sky can bypass the secondary mirror, pass through the hole in the primary mirror and then enter the observer's eye. To eliminate or minimize sky flooding, *baffle tubes* are placed in Cassegrainian type telescopes (see the drawing on this page). Generally, the larger baffle extends through the hole in the primary mirror toward the secondary mirror and in extreme cases, a short baffle extends from the secondary mirror toward the primary.

BAFFLES STOP SKYLIGHT FLOODING



The Cassegrainian type telescopes, due to the active role of the small convex mirror, are much more sensitive to alignment than the Newtonian. In portable instruments, misalignment can present a severe annoyance to the observer. The supporting structure and adjustments in these compound instrument designs must be of higher quality than they are in simpler instruments (such as Newtonians) if you expect to be able to transport them about and secure the image quality they are capable of providing when perfectly aligned.

Editor's Note: Our next installment will cover catadioptrics — telescopes that combine lenses (dioptric elements) and mirrors (catoptric) — as well as some very unusual and intriguing new telescope designs.

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GAZER'S GAZETTE

Learning the Constellations
Part 2: Spring

by
Henry J. Phillips

After the bitter cold of most winter nights, warm spring evenings are suitable for all sorts of activities. Surely learning the spring constellations is among the most enjoyable of these. If you're familiar with the star groups of winter from our first article in this series (see ASTRONOMY, December 1977), you'll find that spring's star patterns require a bit more effort to trace out and remember. There aren't as many bright stars scattered throughout the spring sky as there are in winter, but the spring patterns seem to have a friendliness and softness that is unlike the hard glassy brilliance of winter stars. This may be an illusion brought about by warmer weather, but the effect on us of the spring sky is entirely different from that of winter.

By far the best place to begin our survey of the spring constellations is with the group that is probably the most famous of all: the **Big Dipper.** It lies almost overhead for most United States observers during spring months and is an excellent guide to many of the other groups visible at this time. In addition, the Big Dipper's pattern, although familiar to almost everyone, is a strangely compelling one to which we return again and again without tiring — even though it contains no first magnitude stars.

The two stars at the end of the Big Dipper's "bowl" are named *Merak* (MARE-ak) and *Dubhe* (DOOB-ee). Together they are called the pointers, because a line from Merak through Dubhe points almost exactly to the sky's north pole, which is marked by the bright star *Polaris* (pole-AR-is) — otherwise known simply as the "North Star". Polaris is the brightest star in the **Little Dipper**, a much less conspicuous figure than its larger companion.

Strangely, the Big Dipper — although an eye-catching and easily recognizable group — doesn't form a constellation by itself, but is only part of the much larger constellation **Ursa Major** (UR-sah MAY-jor), the big bear. The Dipper represents the bear's hindquarters and greatly elongated tail; the animal's head and paws are marked by dimmer stars or pairs of stars west and south of the Dipper's bowl. Similarly, the Little Dipper forms the much smaller Ursa Minor, the little bear; it, however, contains most of the constellation's visible stars.

Because the Big Dipper is so near the pole, it's visible almost all year from most parts of the U.S. We include it in our spring survey because it's highest at that time, and also because its stars can serve as pointers to other stars besides Polaris. For example, if you draw a line south through the other two stars in the Big Dipper's bowl, you'll come upon the constallation **Leo** (LEE-oh), which has the most clearly marked pattern of any of the spring groups. Its main feature is the sickle, a group of six stars resembling that tool (nowadays we might think of it as a backwards question mark). Leo is meant to represent a lion, and the sickle also stands for the animal's head and mane. The star at the base of the sickle is first magnitude **Regulus** (REG-you-lus), which marks the lion's heart and has a bluish-white color. Regulus is one of only three first magnitude stars included among our spring constellations, and is hard to miss. The rest of Leo, east of the sickle, forms a

Top: Of all the celestial configurations, the Big Dipper may well be the most famous one of all (actually it's part of the constellation Ursa Major). The Big Dipper is visible all year round, and its shape is easy to recognize even though none of its stars are exceptionally bright. From the left, the second star in the handle is actually two stars, Mizar and Alcor (Alcor is the fainter). In ancient times the pair was used as an eye test; if you could see the two, your vision was considered normal. Photograph by James MacDougall. Bottom: This photograph shows the constellation Leo, more commonly referred to as the lion. Regulus is located in the lower right portion of the photo. Using *it as a starting* point, you should be able to trace upward to the "backwards question mark" that forms the head of the lion. Photograph by Bob Kimmel.

right triangle; the brightest of its three component stars is named **Denebola** (den-EB-oh-lah).

Leo is in the zodiac, so at one time or another you can expect to see our moon or a planet located there. Also in the zodiac, but much dimmer, is Leo's neighbor to the west, **Cancer** (KAN-sir). Cancer is, in fact, the dimmest of all the zodiacal constellations, but it does contain one object worth searchin for: the large open cluster known as the Beehive, visible as a hazy patch to the naked eye on clear moonless nights and a thrilling sight in binoculars.

Southwest of Leo lies a single bright star in an isolated position. This star's name, **Alphard** (AL-fard), is fitting because it means "the lonely one". Alphard is the brightest member of the long, sprawling constellation **Hydra** (HIE-drah), which represents a sea serpent. Alphard marks the serpent's heart; the head is a pretty group of stars just south of Cancer (binoculars are good here too). The rest of Hydra stretches far to the east and south. Balanced on Hydra's back, southeast of Alphard, are two small but distinct constellations: **Crater** (KRAY-ter) and **Corvus** (KOR-vus). Crater means cup, and this group's stars do form a bowllike pattern. But you'll have to look hard, as its stars are faint and easily blotted out by haze or moonlight. Corvus the crow, to Crater's east, is easier to see; its four brightest stars form a quadrangle that glows due south on May evenings.

Leo is bordered on the east by another constellation of the zodiac: **Virgo** (VEER-go), the virgin. Virgo is very large but doesn't have much to show for its size. It does contain one first magnitude star, *Spica* (SPY-kah), which — like Regulus — has a faint bluish tinge; it's also slightly brighter than Regulus. Spica is located north of Corvus and Crater and serves as a guide to those two small groups.

The rest of Virgo forms a large, vaguely Y-shaped pattern. Spica is the base of the Y, and its two arms branch north and northwest toward Denebola. In addition, two parallel streams of stars extend east from Spica. Many of these stars are faint; it takes a clear night to see the constellation plainly.

Returning now to the Big Dipper, we find two small constellations located between it and Virgo. Beneath the Dipper's handle lies a tiny figure of two stars that bears a strong resemblance to Canis Minor, even to the extent that one of the stars is brighter than the other (although not first magnitude). The constellation is **Canes Venatici** (Kay-neez ven-AT-is-see), and the brighter star is named *Cor Caroli* (kor kah-ROE-lee). south of this tiny group, between it and Virgo, lies the very faint **Coma Berenices** (KOE-mah bear-uh-NIE-seez), which is actually nothing more than a large extended open cluster. Here is one place where binoculars really help; what may appear as nothing more than a cloudy patch to the naked eye is suddenly resolved into a lovely network of faint stars, the brightest of which form an upside-down Y. (There seems to be an overabundance of Y shapes — large and small — in the spring sky!)

The Big Dipper serves as guide to yet another star — one much brighter than those we've just encountered. The stars in the Big Dipper's handle have a gentle curve; if we continue this curve across the sky, we come upon the orange first magnitude star *Arcturus* (ark-TOOR-us), the brightest star in the constellation **Bootes** (BOW-uh-teez), the herdsman. A simple rule for finding Arcturus is to remember the saying, "Follow the arc to Arcturus." (If we continue this arc, in fact, we come upon Spica, another first magnitude star.) Arcturus is the fourth brightest star in the entire sky and forms a fitting climax to the progression of spring constellations.

Bootes itself is a fairly large group; its characteristic shape is a large diamond, often called the "kite". Arcturus is at the bottom tip of the kite, with the rest extending north and including several fairly bright stars. If you can't make out the kite, others have professed to seeing a large ice cream cone!

This concludes our survey of the spring constellations for observers in most of the U.S. Those who live in the far southern parts of the nation (including Hawaii), however, are treated to a sight during spring evenings that others must travel long distances to enjoy. We're referring to the magnificent constellations **Centaurus** (sen-TOR-us) and **Crux** (the southern cross) which, lying as far south as they do, cannot be seen from most of the U.S. (except for the northernmost sections of Centaurus). Each of these groups contains two stars of first magnitude.

For those of you in southern locations, Crux lies due south of Corvus and just brushes the southern horizon (because of horizon haze and low lying clouds). Centaurus, which surrounds the cross on three sides, is very much larger and is simply breathtaking in the number of its bright stars. You'll never forget your first sight of it!

If you've never tried learning the constellations, spring, with its milder evening temperatures that induce us out-of-doors, is certainly a good time to start. Even if the visible stars aren't as bright as those of other seasons, there are attractions to be discovered in the spring sky; if you miss them now, you'll have to wait a whole year before they come around again! Take advantage of the opportunity afforded by pleasant nights to begin your acquaintance with some of mankind's oldest friends — the stars.

Top: Cancer, also known as the crab, is the faintest of all the zodiac constellations, so you may need a clear night to observe it. Cancer is Leo's neighbor to the west and has a shape somewhat similar to an upside down "Y". Photograph by Stephen A. Walther. Bottom: Hydra is one of the lesser known constellations, but it does have a redeeming feature — it's the largest of all the constellations. Hydra, also known as a sea serpent, has a long snakelike appearance making it rather easy to identify. Photograph by Bob Kimmel. You can take constellation photographs like the ones shown in this article. All you need is high speed film (ASA 400), a camera, and a tripod. Set the aperture of your camera wide open and time your exposure for 10 seconds. With a little luck you should get some excellent results.

Meade precision 6" and 8" reflecting telescope systems give you full photo-visual capabilities.

Meade 6" and 8" reflectors achieve a new level of optical and mechanical excellence for the serious amateur. These totally integrated telescope systems include everything required for detailed study of the Solar System and Deep Space, and readily permit the observer to grow into more advanced subjects, such as long-exposure astrophotography. Designed by Meade engineers and manufactured at our Costa Mesa facility, these telescopes possess capabilities generally obtainable only at much higher prices—and they are the only telescopes available which use exclusively the quality Meade components known throughout the astronomical world.

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Easy Portability: Meade 6" and 8" reflectors readily break down into 3 sub-assemblies for quick and easy transport in the field. Setup time is about 5 minutes.

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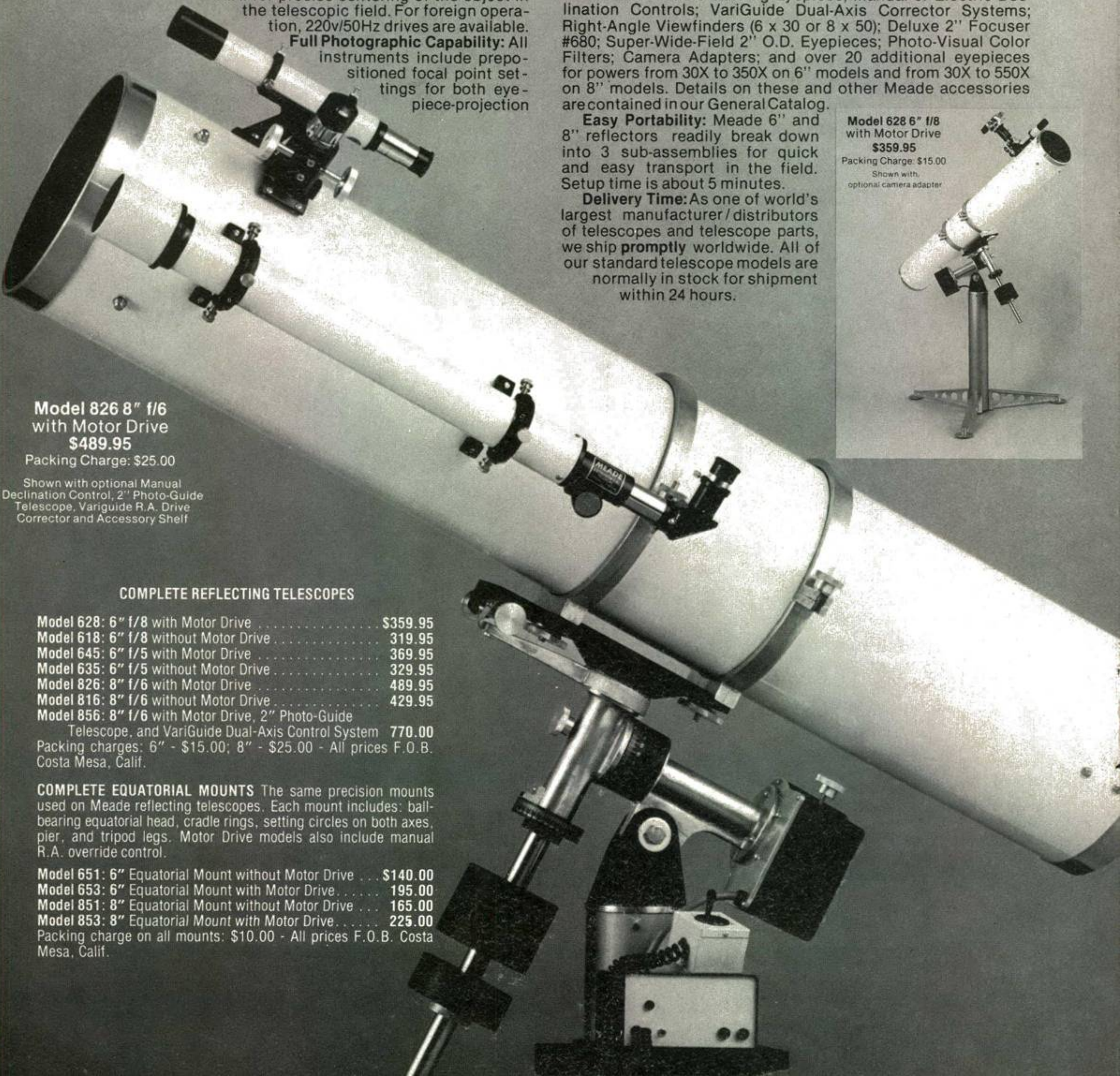
Packing Charge: $15.00
Shown with optional camera adapter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with Motor Drive
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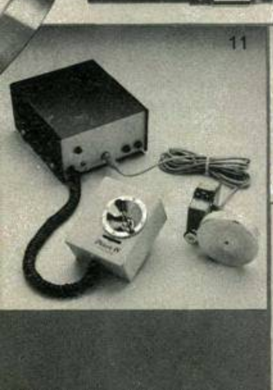

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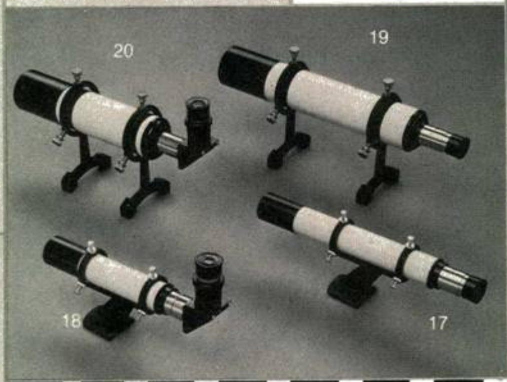

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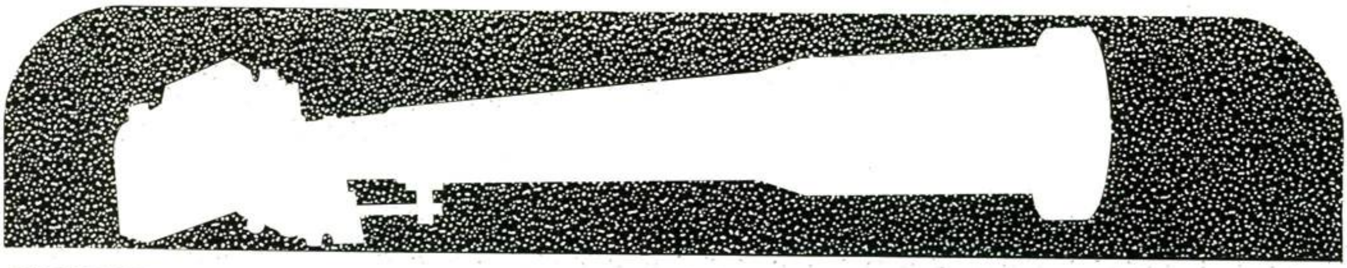


PHOTOGRAPHY IN ASTRONOMY

Capture a Galaxy on Film

by
Richard Berry

Galaxies are the big game animals of astrophotography — they're enormous, remote and terribly awesome. Successful astrophotographers may hang up a colorful picture of the Orion nebula or show a nice shot of the Lagoon nebula glowing red, but it's often a galaxy picture that's framed and displayed like a big game trophy in a place of honor. Whether it's their size, their distance, their wonderful symmetry, or simply the challenge of bagging such an elusive target, the urge to try photographing a galaxy is almost irresistible to an astrophotographer.

But it isn't easy. Galaxies are less bright than the showy H-II regions of the Milky Way, and they are liable to fade quietly into the gray of the night sky in the presence of artificial lights. Though a few of the brightest galaxies have large angular diameters, most are small. Careful guiding, accurate focusing and proper film choice, as well as a focal length adequate to the small size of the galaxy image, are all critical in obtaining fine results.

Let's look at a few of the outstanding characteristics of galaxies, and then consider how best to photograph them. Galaxies — especially their outer parts — have a low surface brightness, generally only a few times brighter than the natural sky brightness. When light pollution raises the level of the sky background, the contrast of a typical galaxy image decreases, much as the view decreases when a dirty automobile windshield robs contrast from the driver's view. Dark skies are a must. Even though you can see the inner regions and nucleus of the brighter galaxies from a city, the spiral arms are lost in the skyglow. A light pollution rating of five (see "Light Pollution: A Losing Battle?", September 1977) guarantees reasonable galaxy contrast.

Galaxies, with the exception of M-31, M-33 and the Magellanic Clouds, have images significantly smaller — often 1/5 to 1/10 — than that of the full moon. One of the larger and more impressive spirals, the Whirlpool (M-51), is only 1.5 by 3 millimeters at the focus of an eight inch f/5 reflector (an instrument well-suited for galaxian photography). Clearly there is little allowance for sloppy guiding or poor focus, which can smear the tiny image.

Finally, galaxies don't respond to the red filter techniques invaluable in photographing nebulae (see "Red Light Sky Photography", August 1976), because the significant detail (the spiral arm structure) is predominantly blue. While red filter techniques can help a little in reducing the background light, the best result will come from blue sensitive emulsions used far from light pollution. This happens because the galaxy's arms are brightest in the blue and violet parts of the spectrum, while the natural light from the sky is dimmest in the blue and violet. Mercury vapor lamps — by some fateful coincidence — are high powered and blue-violet polluters!

What, then, is the minimum equipment requirement for recording a galaxy on film? Answer: The 50mm lens on your 35mm camera! The galaxy viewed

Books That May Help You . . .

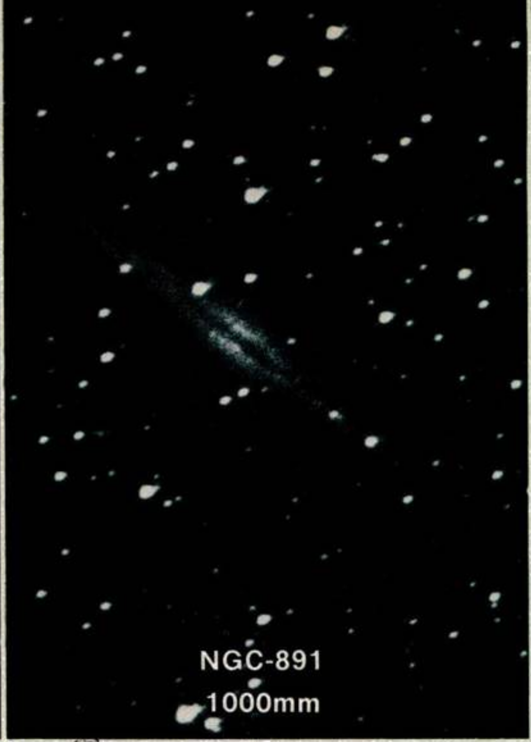
Astrophotography Near City Lights by Joseph Cocozza — a "how-to" on astrophotography; some pictures of galaxies.

Deep Sky Objects by Jack Newton — photographs of all the Messier objects; especially useful in the Virgo cluster region. All pictures are on the same scale permitting valuable intercomparison.

Atlas Coeli 1950.0 & Atlas Katalog by Antonin Becvar — a fine star atlas and list of the objects in it; data on hundreds of galaxies.

Fine galaxy pictures come from many sizes and types of telescopes — from telephoto camera lenses through 16 inch Newtonian giants, to the light, portable catadioptrics. What really counts is the system's focal length: the longer the focus, the bigger and sharper the image. The focal length used is at the bottom of each picture; at the top is its Messier or *New General Catalogue* number. Photo credits left to right, top to bottom: Orien Ernest, Bill Iburg, Leo Henzl, Martin Germano, Evered Kreimer, Bill Iburg, Bill Gordon, Evered Kreimer, Leo Henzl.

M-104
2000mm



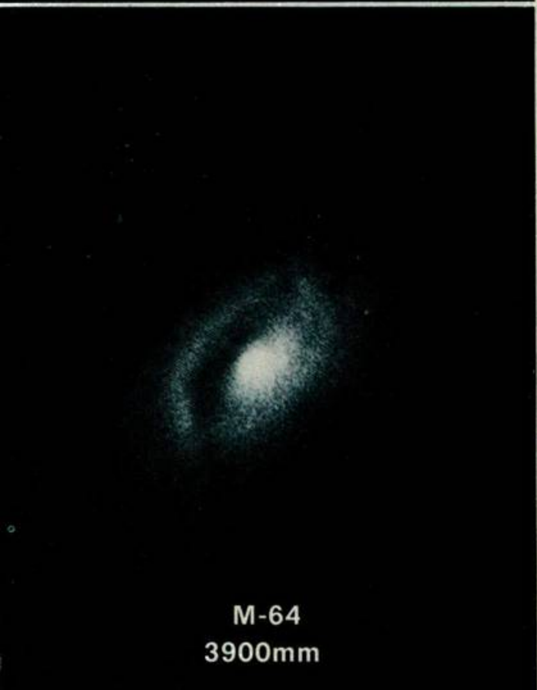
NGC-891
1000mm

M-51
3900mm

M-81
1000mm

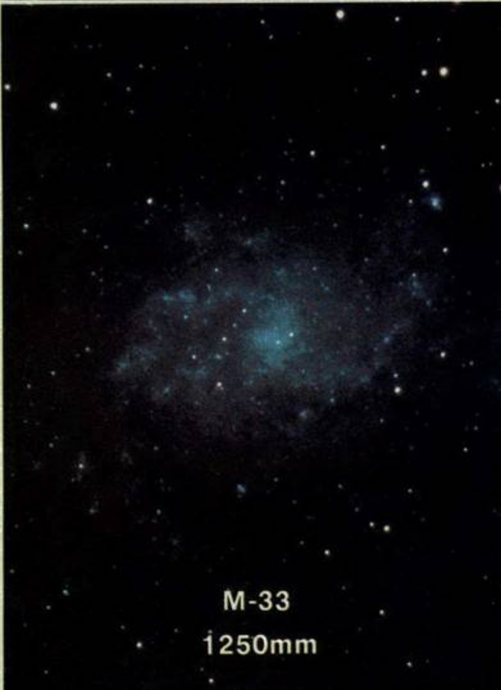
NGC-4631
2200mm

NGC-4565
1000mm

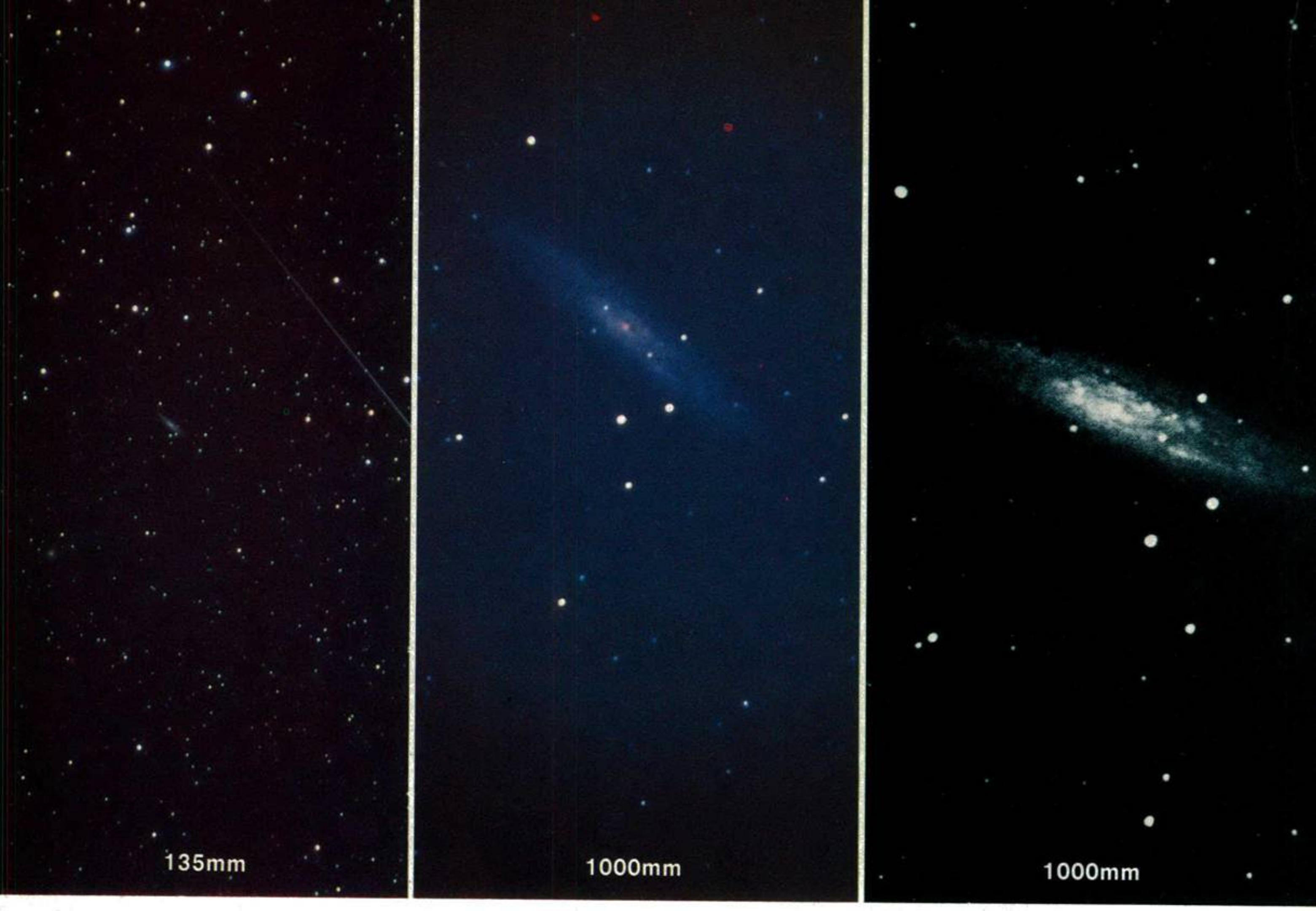


M-64
3900mm

M-101
2200mm



M-33
1250mm



Above, left to right: NGC-253 shows up as a subtle smudge with a 135mm telephoto in this 35 minute exposure at f/2.5 on Fuji R-100 film; with the 1000mm focus of a Celestron with telecompressor (45 minutes on Fuji R-100 at f/5), real galaxy detail begins to show. On 103aE film (30 minute exposure, at right), far fainter details are shown, as well as more structure in the spiral arms. Photographs by David Healy. Opposite page, top left: M-51, perhaps the finest spiral in the sky, does not readily yield its image to a telephoto lens. This GAF 500 exposure was one hour at f/6.3. Photograph by Jim McDowell. Top right: The 1000mm focal length of an eight inch f/5 Newtonian could and did record spiral structure in this 30 minute GAF 500 exposure. Photograph by Robert Kimmel Sr. Bottom left: Bigger optics mean more detail. This 12 minute exposure on 103aF film with a 12-1/2 inch f/4.8 Newtonian is not well guided, but nevertheless records more. Photograph by August Schug. Bottom right: Sixteen inch Newtonian optics, color film, and cold camera techniques combine to produce detailed images in short exposure times. Photograph by Orien Ernest.

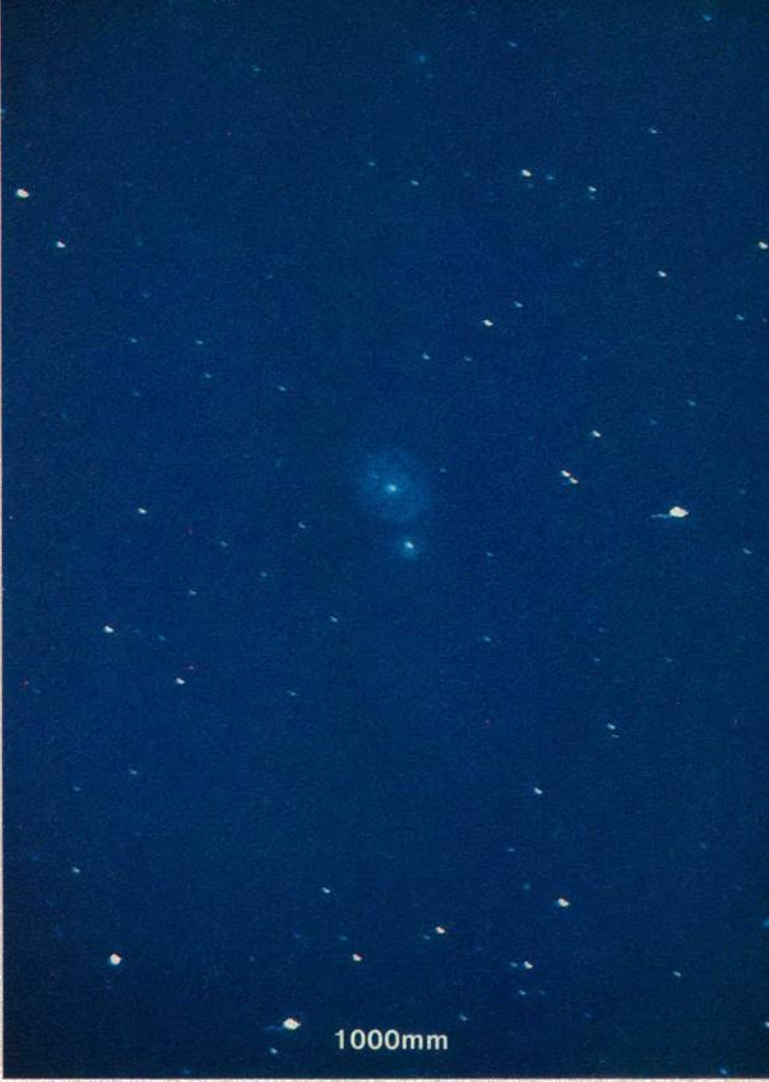
will be the Andromeda galaxy (M-31) or, if you live in the southern hemisphere, the Magellanic Clouds. Even the shortest exposures taken with the camera piggybacked on a telescope — say a minute or two with fast film in the camera — will suffice. From a dark country observing site, longer exposures (10 to 20 minutes on fast color or black and white films) will show the full three degree extent of this galaxy.

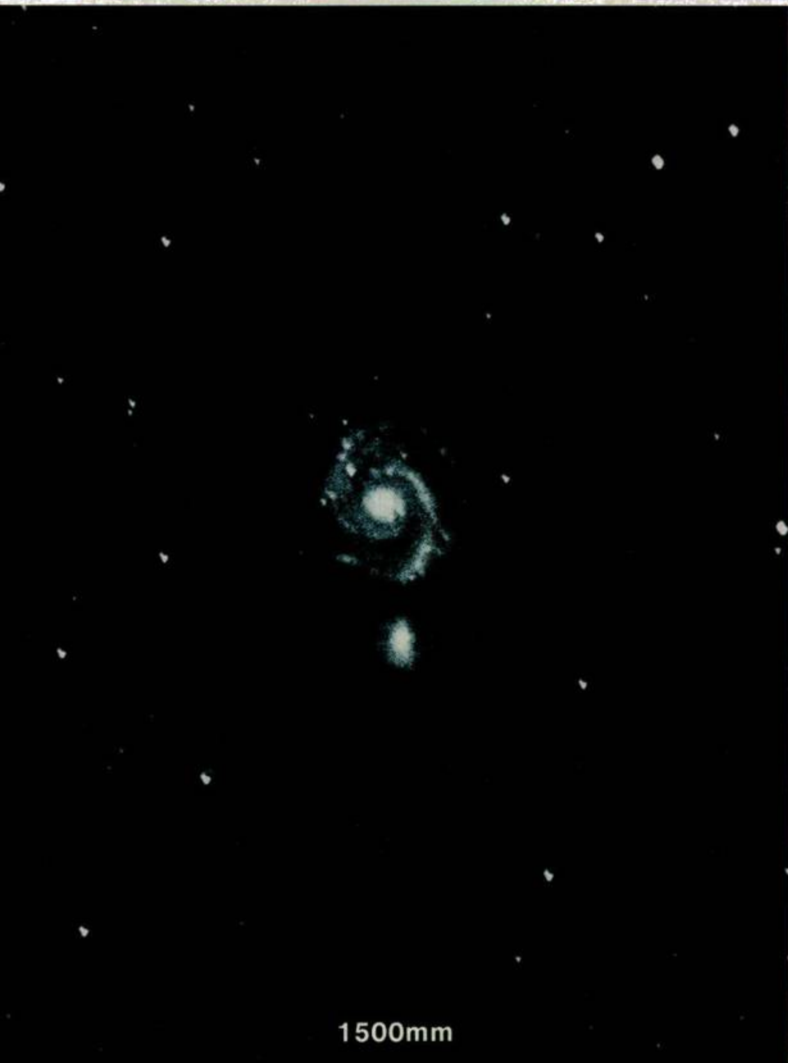
Of course, a telephoto lens will enlarge the galaxy image in the most satisfying manner. With a 200mm or 300mm focal length, other galaxies become accessible as well: The Triangulum spiral (M-33) shows its arms, whle NGC-253 and NGC-891 become tiny elliptical blobs (interesting, but not yet identifiable as galaxies). At a focal length of 400 to 500mm their true nature finally emerges; the Whirlpool resolves into a tiny beautiful twin swirl, the dust lanes of the Andromeda galaxy at last emerge, and the more distant galaxies of the Virgo cluster (see this month's Star Dome) become tiny hazy objects of intrigue (not just fuzz but spiraled fuzz!). Exposures with a typical f/6.3 to f/8 "girl watcher" lens telephoto will run 30 to 60 minutes on Tri-X film, or about 20 minutes on Kodak's spectroscopic emulsions 103aF or 103aE. Although the blue sensitive 103aO might give better image contrast (as mentioned above), the color correction of telephotos usually isn't good enough to give sharp images in blue and ultraviolet light.

It's worth studying the photos printed here carefully to see just what you'll get with the different focal lengths. And it's important not to become discouraged because pictures made with telephotos from your own backyard don't compare with the pictures printed here, showing what a 12 or 16 inch telescope used with a cooled emulsion camera can yield. Remember that everybody started somewhere. Besides, the big thrill is in bagging your own game, not trying to set the world's record!

Though fine results can and do come from 600mm focus systems (such as the classical six inch f/4

400mm


1000mm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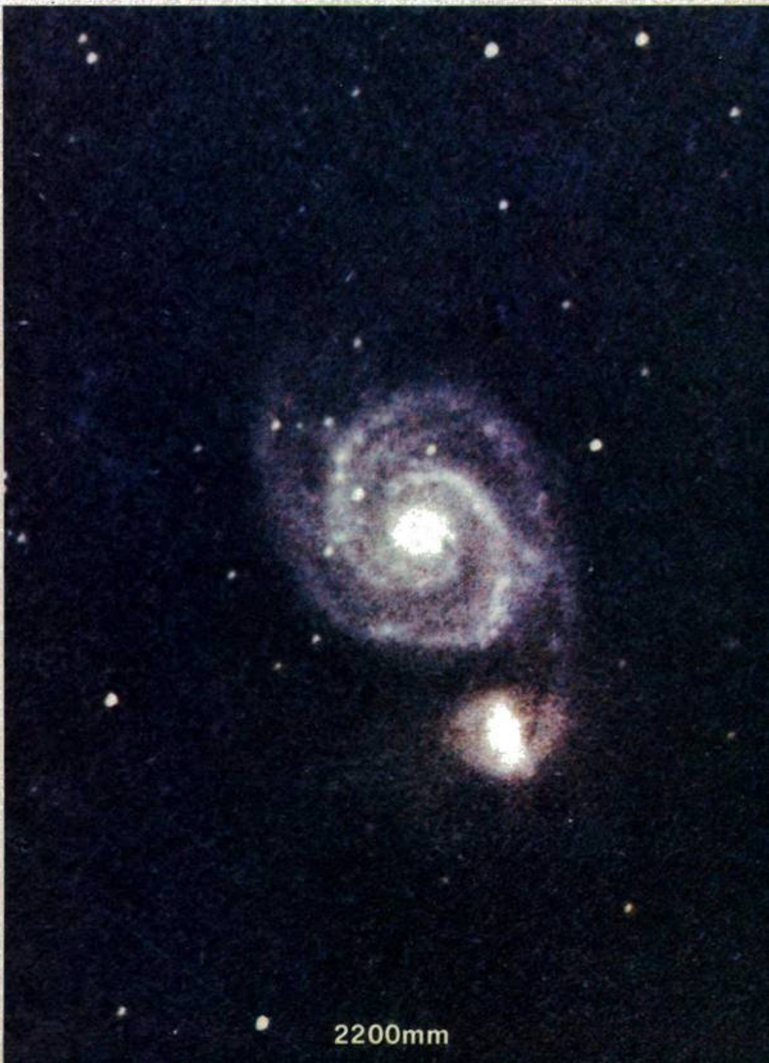
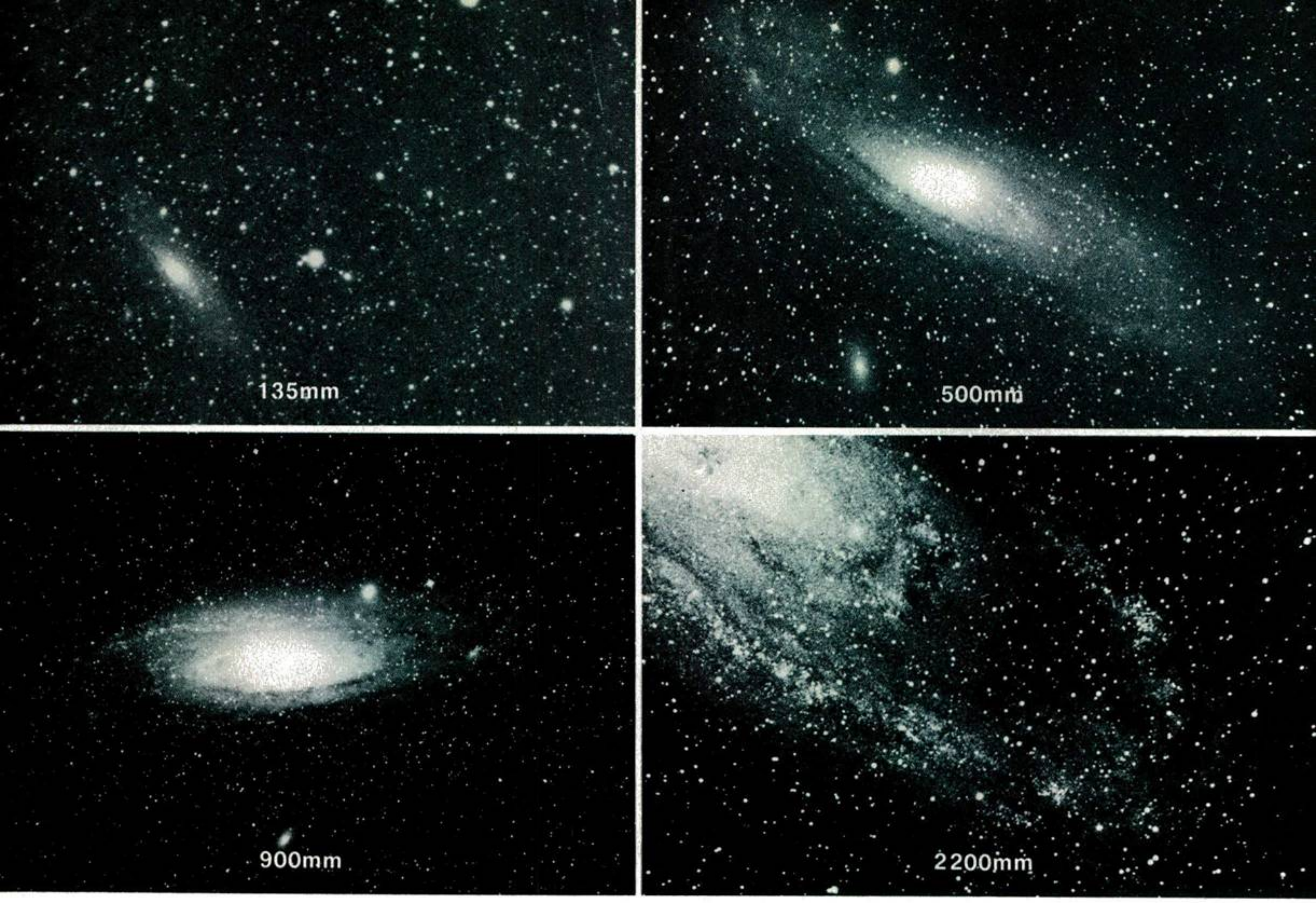

2200mm



The "nebula" in Andromeda is the first target for beginning astrophotographers — but you'll come back to it again and again, no matter what your equipment! Upper left: a 135mm f/2.8 telephoto lens was used with Tri-X film to record Andromeda in a 20 minute exposure. Photograph by Jon Hanford. Upper right: A 4-1/4 inch RFT reflector working at f/5 was used for a nine minute exposure on 103aF film. Photograph by Dana Patchick. Lower left: A six inch reflector, dark skies, and spectroscopic emulsion produce crisp images of our galaxy's neighbor. Photograph by Robert Provin. Lower right: A 12 inch reflector can probe the details of the arms of the spiral; starclouds and dust lanes show clearly. Photograph by Evered Kreimer.

RFT), the breakthrough in pictorial results comes when you pass the 900mm focal length barrier. Reflecting optics are a necessity: They allow you to use the blue sensitive spectroscopic films, and in addition are very much sharper than most equivalent refracting optical systems. Reflecting optics offer large aperture and high speed at a low price. Although not noted for wide fields of view (because of off-axis coma), it should be obvious that galaxies seldom require a large field.

There is no ideal focal ratio — the reflecting telescope you already have will probably do. The real limitation on focal ratio is recording the background sky brightness before you get tired of guiding. With an f/4 mirror you can reach the sky background in 15 minutes or so. With an f/8 mirror, the reciprocity failure effect means that you might have to guide up to two hours to reach background! The spectroscopic films are less affected by reciprocity failure — 40 to 50 minutes is typical on 103aF at f/8 from a good sky location; 10 minutes is typical at f/4. The best compromise focal ratio is probably f/5 if you're using Tri-X or color films, and f/7 or f/8 if you're using the spectroscopic films or a cooled emulsion camera (cold camera). Offsetting the longer guiding times of the larger f-ratios is the larger image size, which in turn means better resolution and more detail. Your extra guide time will be proportionately compensated, in fact, with more image information.

Obviously the next step is to make the mirror bigger to increase the photographic speed of the system. The trend is thus inevitably toward very large aperture high speed telescopes, culminating in the Palomar 200 inch f/3.3 and Kitt Peak 158 inch f/2.7 reflectors!

If you are a beginning astrophotographer, check some of the articles and books listed on page 42; they'll help you with basic problems such as attaching your camera to the telescope, guiding, selecting the best films for galaxy hunting, and making the exposure. If you're an old "pro", the galaxy listing on page 47 may help you. You'll recognize many old friends on the list, plus some lesser known — but magnificent — spirals within the range of telescopes with 600mm or longer focal lengths. And look at the pictures, of course; they show that the galaxies are not beyond your grasp!

Messier Number	NGC Number	Size* mm/mfl	Photo-graphic Bright-ness**	Com-ments***
	205	2x1	med.	E
31	**224**	**28x8**	**v. br.**	**sp.**
	247	4x1	faint	sp.
	253	**5x1.5**	**br.**	**sp.**
	300	2	faint	
	428	0.4	med.	
	488	0.5	br.	
33	**598**	**10x7**	**med.**	**sp.**
	613	0.6	med.	
74	628	1	med.	t. sp.
	672	0.6x0.4	faint	sp.
	694	0.4	faint	nr. 1 Ari
	772	1x.5	med.	2 arm sp.
	891	2.5x0.4	med.	edge-on
	1023	0.7x0.3	med.	sp.
	1055	1x0.4	med.	
	1068	0.5	med.	nr. br. star
	1073	0.8	faint	sp.
	1097	1	br.	bar. sp.
	1232	1	faint	face-on sp.
	1300	1	faint	bar. sp.
	1365	1	faint	bar. sp.
	1532	1.5x0.3	med.	edge-on sp.
	2403	1.5x1	br.	sp.
	2683	2x0.3	med.	edge-on sp.
	2841	1x0.5	br.	sp.
	2903	**1x0.5**	**br.**	**sp.**
	2997	1	med.	face-on sp.
81	**3031**	**3.5x2.5**	**v. br.**	**sp.** } pair
82	**3034**	**2x1**	**v. br.**	**irreg.**
	3079	1.5x0.4	med.	sp.
	3189	1	med.	face-on sp.
	3198	1x0.5	med.	sp.
	3344	0.8	faint	nr. star γ Leo
	anon.	0.5x0.3	med.	pair nr.
95	3351	0.7	br.	
96	3368	0.6	med.	ft. arms
105	3379/3384	0.5	med.	pair
	anon.	0.7x0.3	med.	nr. 58 Leo
	3423	0.5	med.	
	3486	0.5	med.	sp., ft. arms
	3521	1.5x1	br.	
108	3556	1.2x0.4	med.	sp.
65	**3623**	**1.5x0.4**	**br.**	**sp.** } group
66	**3627**	**1.5x0.7**	**br.**	**sp.**
	3628	**3x0.7**	**med.**	**ir. sp.**
	3646	0.5x0.3	med.	sp.
	3726	0.5	med.	sp.
	3877	1x0.3	med.	sp.
	3810	0.5	br.	
109	3992	1	faint	
	4026	0.5x0.3	med.	sp.
	4030	0.5	br.	
	4038	0.4	med.	
	4088	0.6x0.3	med.	sp.
	4151	0.7	med.	sp.
	4157	0.5x0.2	med.	sp.
98	4192	1.5x0.3	med.	edge-on sp.

Messier Number	NGC Number	Size* mm/mfl	Photo-graphic Bright-ness**	Com-ments***
	4214	0.5	br.	ft. arms 1mm
	4216	2x0.4	med.	edge-on sp.
	anon.	1x0.2	med.	edge-on sp.
	4236	2.5x1	faint	sp.
	4244	3x0.3	med.	edge-on sp.
99	4254	1	br.	sp.
106	4258	4x2	med.	sp.w/ft. arms
	4293	0.8x0.3	med.	sp.
61	4303	0.5	med.	sp.w/ft. arms
100	**4321**	**1.3**	**br.**	**face-on sp.**
84	4374	0.6	br.	E } center of Virgo cluster field
86	4406	0.6	br.	E
	4435	0.4x0.2	med.	
	4473	0.5	med.	
	4477	0.4	med.	
85	4382	0.8x0.6	med.	E
	4395	2	faint	ir.
49	4472	0.8	med.	E ft. halo
87	4486	0.7	med.	E ft. halo
88	4501	0.5x0.3	med.	E
	4517	2x0.3	med.	edge-on sp.
	4526	1.3x0.4	med.	edge-on sp.
	4527	1.2x0.2	med.	edge-on sp.
	4535	1	faint	sp.
	4536	1.5x0.4	med.	sp.
	4548	0.6	faint	face-on sp.
	4559	1.7x0.6	faint	sp.
	4565	**4x0.4**	**med.**	**edge-on sp.**
90	4569	1.2x0.5	br.	sp.
58	4579	0.6x0.4	med.	E
104	4594	1x0.5	br.	dust lane
59	4621	0.3	med.	E
	4631	**3x0.5**	**br.**	**ir.** } pair
	4656	**1.5x0.4**	**med.**	**dis. sp.**
60	4649	0.6	med.	E
	4725	1.5x1	med.	sp.
94	4736	0.8x0.6	br.	ft. arms
	4754	1x0.2	med.	sp. nr. E
64	**4826**	**1.5x1**	**br.**	**E**
	4856	0.4	med.	
	5005	0.8x0.4	med.	sp.
	5033	2x1	faint	sp.
63	5055	1.5x0.5	br.	sp.
	5068	1	faint	
51	**5194**	**1.3x2**	**v. br.**	**sp. w/com.**
83	**5236**	**2**	**br.**	**sp.**
	5364	0.8	faint	br. nuc.
	5566	2x0.6	faint	br. nuc.
	5371	0.6	med.	sp.
101	5457	3	med.	face-on sp.
	5746	1.5x0.3	med.	edge-on sp.
	5907	2.5x0.7	med.	edge-on sp.
	6822	3x2	faint	ir.
	6946	2	med.	face-on sp.
	7184	0.7	faint	sp.
	7331	1.5x0.5	faint	sp.
	7793	1.5	med.	

Bold face means object is easily photographed.

Anon. = anonymous

* Size is given in millimeters per meter of telescope focal length. To convert to your image size, multiply by telescope focal length in meters. For example, a 10 inch f/7 telescope has a 250mm x 7 = 1,750mm f.l. = 1.75m focal length. The image size of M-33 would be 17mm x 12mm. Ten times photo enlargement would give a final image size 170mm x 120mm, or about 5 by 7 inches.

* * Abbreviations: br. = bright; v. br. = very bright; med. = medium brightness. Classification refers to surface brightness, not total brightness.

* * * Abbreviations: E = elliptical galaxy; sp. = spiral structure is easily visible; t. sp. = tight spiral; bar. sp. = barred spiral; ir. = irregular; ft. = faint; cl. = cluster; dis. = disturbed; com. = companion; nuc. = nucleus. Interesting features (nr. star = near a star, edge-on, face-on, as well as faint outer arms and halos) are noted.

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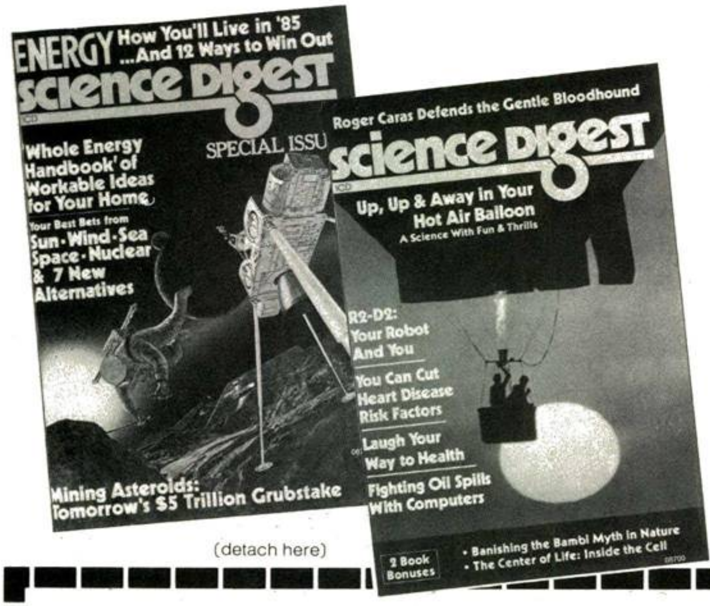

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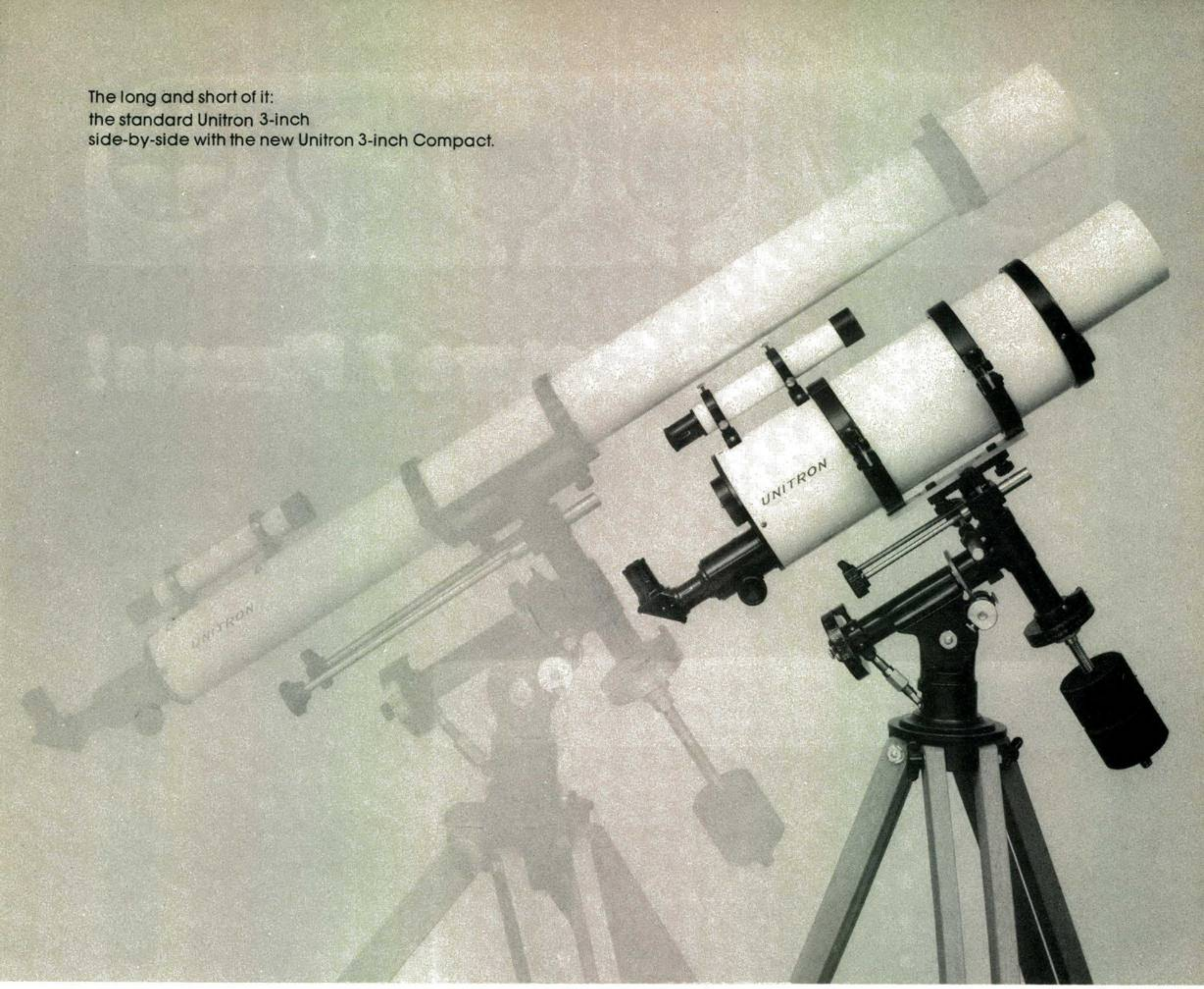

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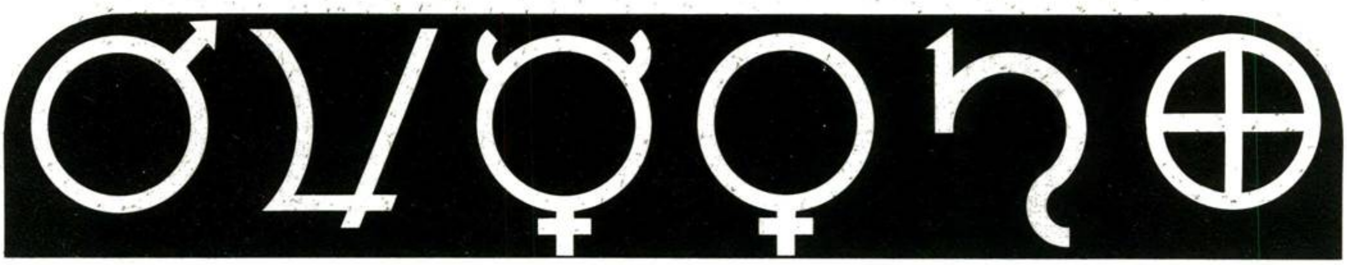


SKY ALMANAC

Evening Skies Feature 7 Planets!

The old saying, "April showers bring May flowers", may be fine for the greenery, but it can be a disaster for astronmers. Hopefully there will be plenty of clear nights for observers to have an opportunity to view seven planets in the evening sky. Three of them (Mercury, Uranus and Pluto) may prove a considerable challenge to observers, but the remaining four (Venus, Mars, Jupiter and Saturn) are easily visible. During the month the moon will pass within a few degrees of Venus, Mars, Jupiter, Saturn and Uranus, making an interesting series for you to see or photograph.

Mercury

At the beginning of April, our solar system's innermost member is rapidly approaching the sun. If you want to observe Mercury, plan to do so on one of the first few days of the month. Look for it low above the western horizon shortly after sunset. You may need binoculars or a small telescope in order to see it.

By the 11th, Mercury will be in inferior conjunction between Earth and the sun and will not be visible for the rest of the month. It will reach greatest western elongation on May 11, but it will be poorly placed. The next *favorable* elongation of Mercury occurs in September, when the planet is located in the morning sky.

Venus

At sunset Venus is easily visible high in the western sky. It shines at magnitude -3.3, making it the brightest object in the evening sky. At the beginning of the month Venus sets about 1 hour 15 minutes after the sun. By midmonth it will set as twilight ends, and by month's end will set two hours after the sun.

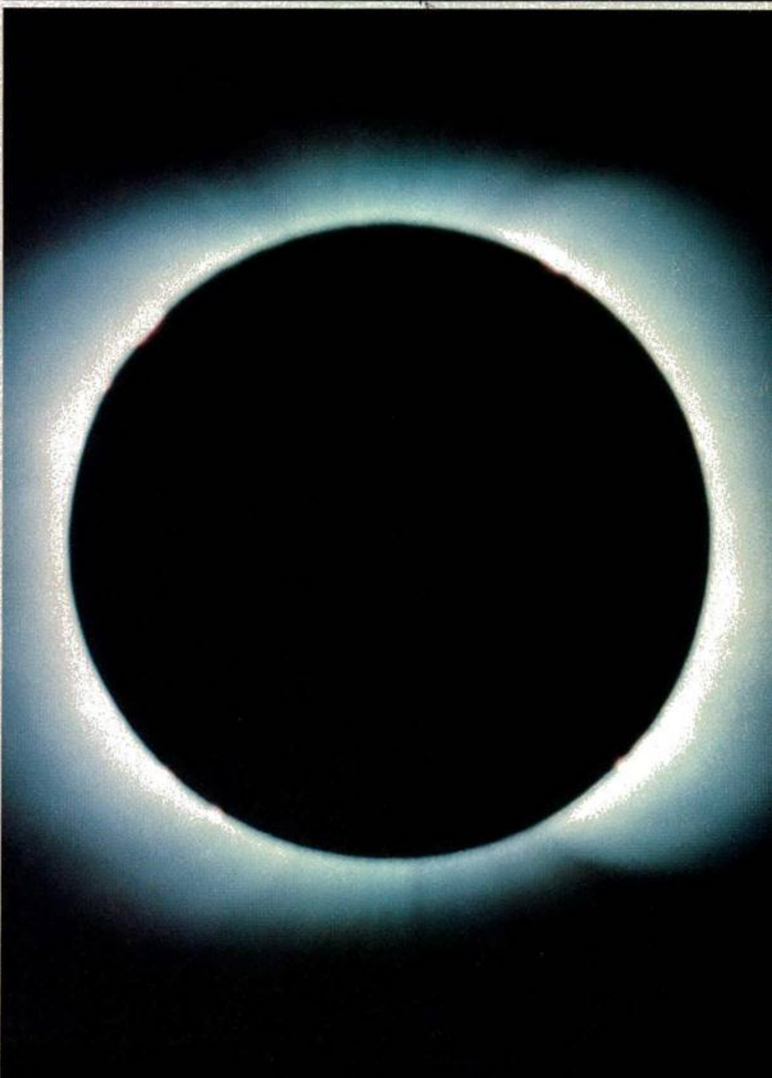
On the 8th the moon will pass three degrees south of Venus, but it will be difficult to see because the moon will appear an extremely thin crescent only 36 hours past new moon. Start looking

April Satellites of Jupiter
10:00 p.m. EST, 7:00 p.m. PST

1	4012	• ●••
2	21043	••●• •
3	2043	• ● ••
4	01234	●• •• •
5	31024	••●• •
6	32014	• • ●• •
7	3104	• • ● •
8	30124	•● •• •
9	12034	••● ••
10	204	• ● •
11	4023	• ● • •
12	41302	• ••● •
13	43201	• • • ● •
14	43120	• • • •●
15	43012	• •●••
16	4103	• •● •
17	42013	• • ●• •
18	4023	• ●• •
19	1042	•● ••
20	32014	• • ●• •
21	31204	• •• ● •
22	30124	• ●•• •
23	1034	• ● • •
24	20134	• ● • • •
25	1034	•● ••
26	01324	●•• ••
27	320	• • ●
28	34120	•• •• ●
29	43012	• • ● ••
30	41023	• • ●••

The four major satellites of Jupiter orbit the planet in periods ranging from less than two days to 17 days. You can see them change position from one night to the next; their motions are often evident after only a few hours' observation. You only need a small telescope to detect all four, and you can frequently make out several in rigidly held (or tripod mounted) binoculars. This table shows the approximate positions of the moons at about 10 p.m. EST on the mornings indicated. The first column on the left shows the date; the second column identifies the moons by their positions relative to Jupiter's disk (1 =Io, 2 =Europa, 3 =Ganymede, 4 =Callisto, 0 =Jupiter's disk). The third column gives the satellites' positions as they appear through a telescope. The orientation of the satellite is given with south up as seen through a standard inverting telescope.

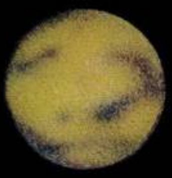
This series of photographs, taken aboard the ship TSS Fairwind, show the solar eclipse of Oct. 12, 1977. Although totality is the stage of the eclipse that is most often photographed, some of the configurations that occur prior to totality can be just as stunning. Upper left: The moon has about a minute before it covers the disk of the sun. Note that even though the brilliant solar disk is not completely covered, pink prominences and the bright inner corona are already visible. Upper right: The sun is almost obscured by the disk of the moon, making prominences and the corona easier to see. Lower left: The photosphere of the sun is now totally covered. At numerous points around the rim, you can see prominences. Note the "polar brushes" in the corona. Lower right: With longer exposure time, the camera records the corona streaming outward along the magnetic lines. These photographs were taken with a five inch Celestron using Ektachrome 200 film. Photographs by M. Marsha Allen.



Planet Finder

Ⓒ Ceres

Apr.	1	15
R.A.	19h16m	19h29m
Dec.	-23°36'	-23°51'
Mag.	+8.0	+7.7

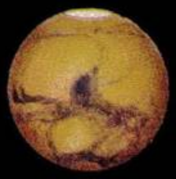


Ⓐ Mercury

Apr.	1
R.A.	1h31m
Dec.	+13°06'
Mag.	+1.4

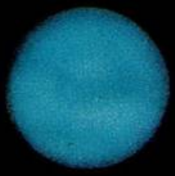
Ⓑ Mercury

Apr.	15
R.A.	1h07m
Dec.	+8°45'
Mag.	+2.7



Ⓜ Mars

Apr.	1	15
R.A.	7h58m	8h17m
Dec.	+23°29'	+22°09'
Mag.	+0.5	+0.8



Ⓝ Neptune

Apr.	15
R.A.	17h09m
Dec.	-21°26'
Mag.	+7.7

SUN

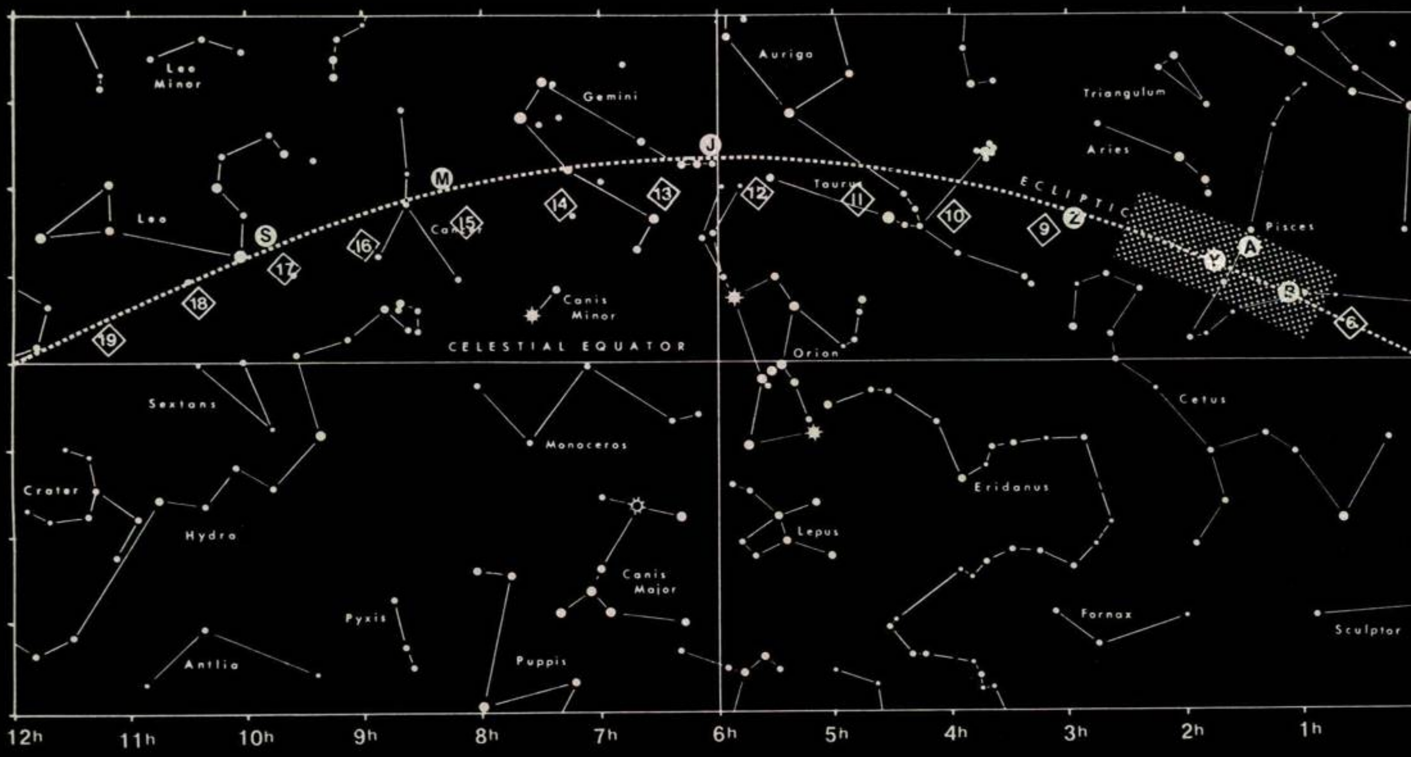
The sun is within the stippled zone throughout the month. Planets and stars near this area are not easily seen.

Ⓢ Saturn

Apr.	1	15
R.A.	9h48m	9h46m
Dec.	+14°55'	+15°03'
Mag.	+0.5	+0.6

Ⓤ Uranus

Apr.	15
R.A.	14h51m
Dec.	-16°00'
Mag.	+5.7


Leo Minor
Gemini
Auriga
Triangulum
Aries
Leo
J
M
Taurus
ECLIPTIC
Z
Pisces
S
Cancer
Y
A
B
19
18
17
16
15
14
13
12
11
10
9
6
Canis Minor
CELESTIAL EQUATOR
Orion
Cetus
Sextans
Monoceros
Crater
Eridanus
Hydra
Lepus
Canis Major
Fornax
Pyxis
Sculptor
Antlia
Puppis
12h
11h
10h
9h
8h
7h
6h
5h
4h
3h
2h
1h

The chart shows the positions of the moon, planets and brightest asteroids for the current month. Letters within the circles correspond to the letters beside each object in the data section above the map. Additional information about each object is given there. R.A. = right ascension and Dec . = declination, the two coordinates used to locate astronomical objects. The general coordinate system is indicated around the edge of the map. Mag . = magnitude, a

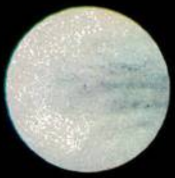
April 1978

Ⓥ Vesta

Apr.	1	15
R.A.	17h10m	17h17m
Dec.	-15°16'	-15°11'
Mag.	+6.3	+5.9

Ⓙ Jupiter

Apr.	1	15
R.A.	5h53m	6h01m
Dec.	+23°24'	+23°26'
Mag.	-1.7	-1.6



Ⓨ Venus

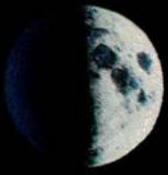
Apr.	1
R.A.	1h43m
Dec.	+10°02'
Mag.	-3.4

Ⓩ Venus

Apr.	15
R.A.	2h49m
Dec.	+16°14'
Mag.	-3.3

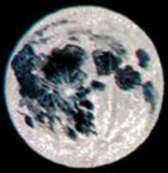
Ⓟ Pluto

Apr.	15
R.A.	13h21m
Dec.	+10°08'
Mag.	+14



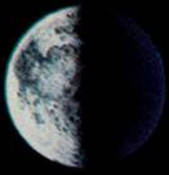
First Quarter

April 15



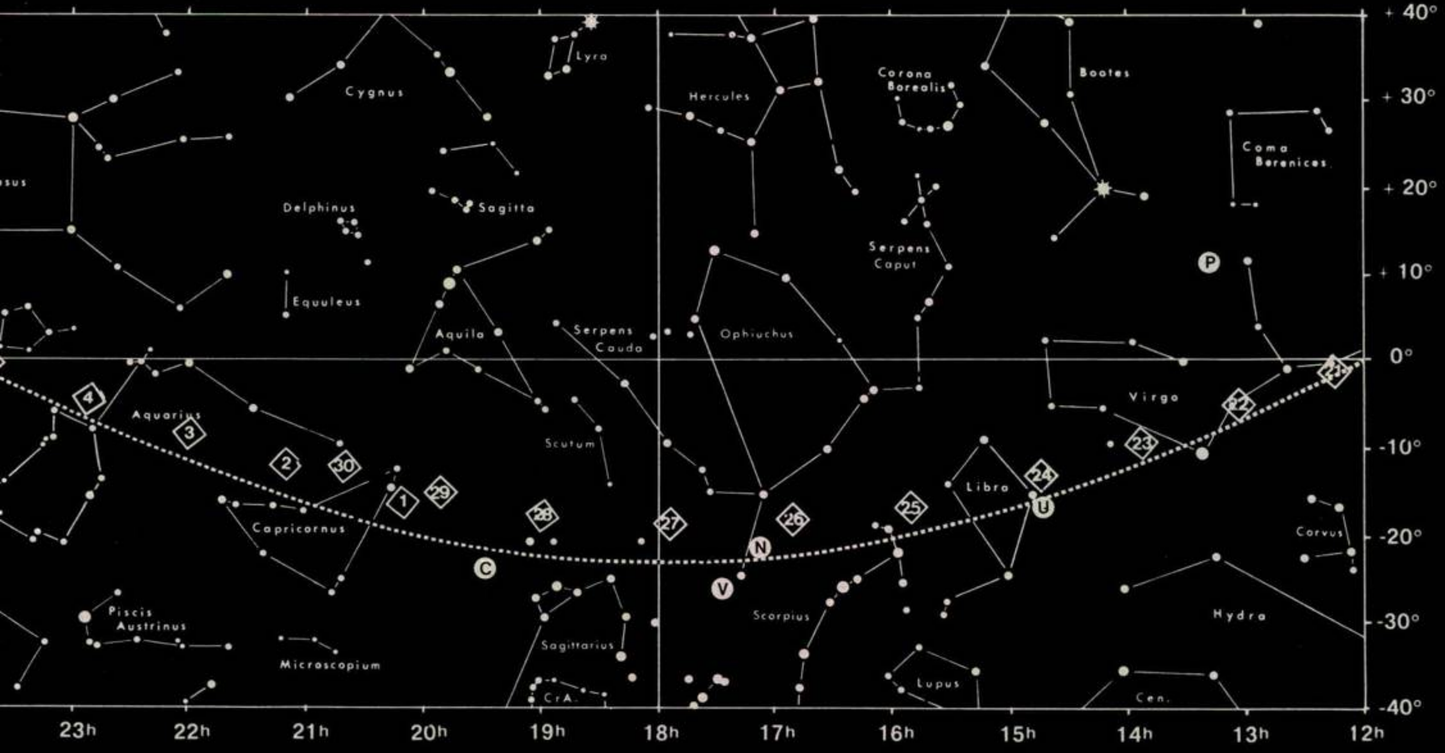
Full Moon

April 23

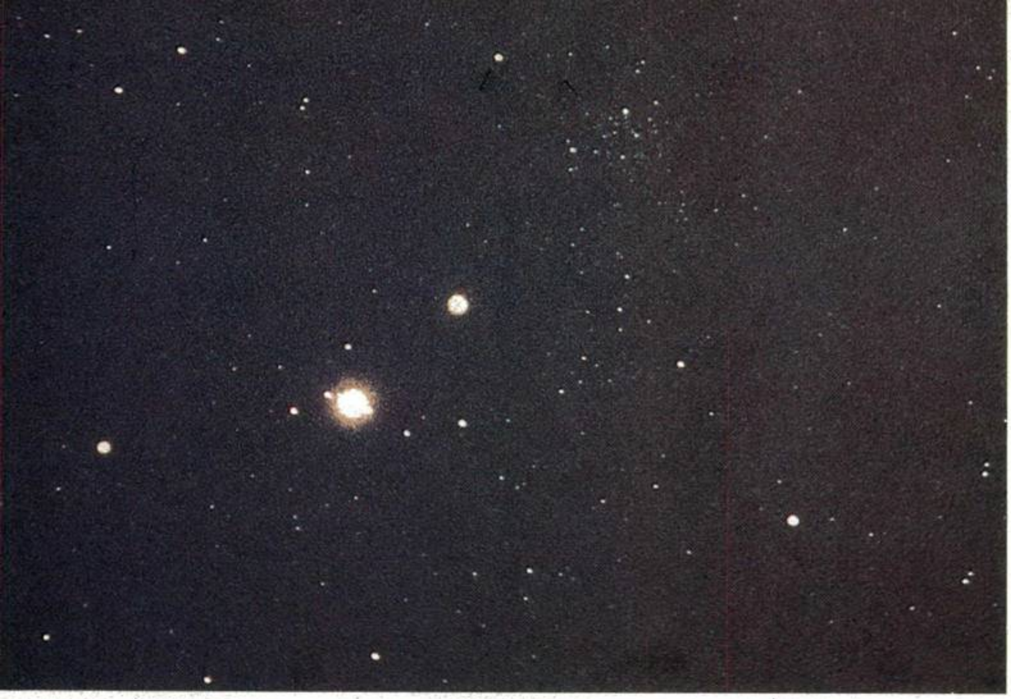


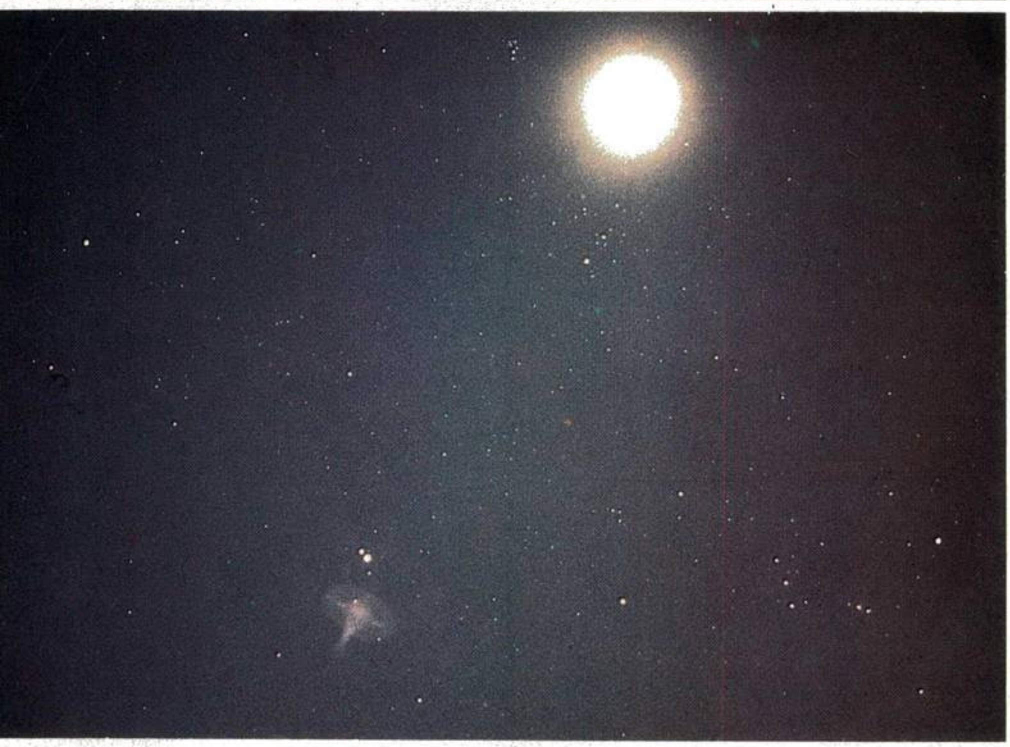
Last Quarter

April 29


+40°
+30°
+20°
+10°
0°
-10°
-20°
-30°
-40°
Lyra
Cygnus
Hercules
Corona Borealis
Bootes
Coma Berenices
sus
Delphinus
Sagitta
Serpens Caput
P
Equuleus
Aquila
Serpens Cauda
Ophiuchus
4
Aquarius
3
Virgo
22
21
2
30
Scutum
23
1
29
Libra
24
28
27
26
25
U
Capricornus
N
Corvus
C
V
Scorpius
Hydra
Piscis Austrinus
Sagittarius
Microscopium
Lupus
CrA.
Cen.
23h
22h
21h
20h
19h
18h
17h
16h
15h
14h
13h
12h

measurement of the object's brightness. (The minus magnitudes indicate very bright planets.) The diamonds with numbers within them indicate the position of the moon for each day of the month; the numbers correspond to the dates. Positions of the planets are for the 15th of the month except for Mercury and Venus which are shown on both the 1st and 15th. Certain areas of this map and the Star Dome chart overlap each month.





for Venus low in the west about a half hour after sunset. You should be able to see it with the naked eye, but if that doesn't work try scanning with binoculars.

Venus moves closer to Earth this month. Its distance from Earth decreases from 150 million miles (240 million kilometers) to 140 million miles (224 million kilometers). In a telescope, it will present a brilliant disk only 11 seconds of arc in diameter, with a 94 percent illuminated gibbous phase.

Mars

Mars, situated in the constellation Cancer, is high in the evening sky after sunset and sets shortly after midnight. Just after sunset at midmonth, it will be almost directly overhead. If you've had a hard time finding Mars, it's because the planet has been dimming rapidly over the past few months. In January, when it was at opposition, Mars shone brightly at magnitude -0.6; at the end of this month it will be at magnitude +1.0. On the 16th, look for the planet seven degrees north of the moon, which will be just past first quarter.

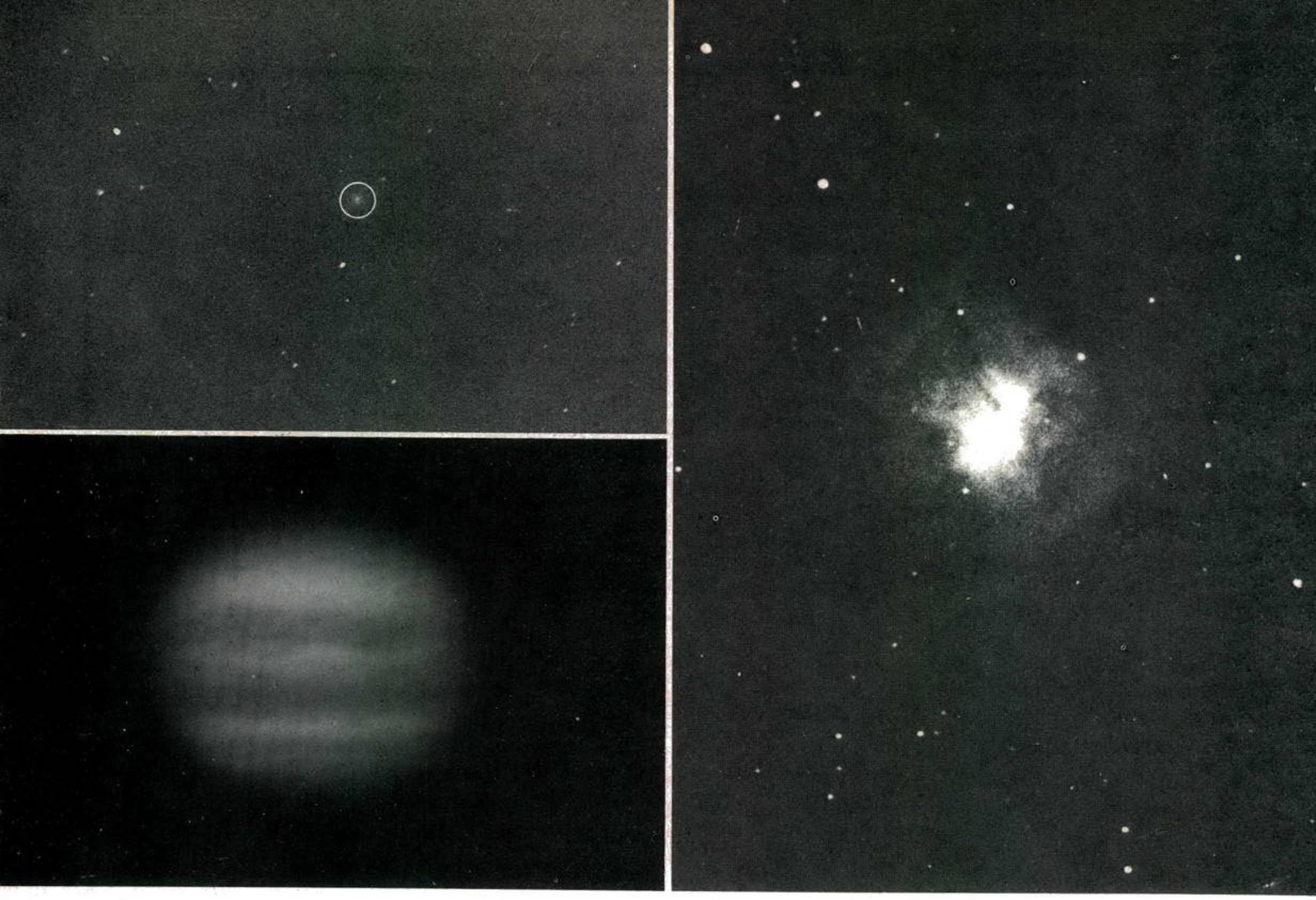
Mars is rapidly moving away from Earth — its distance will increase from 101 million miles (161 million kilometers) to 136 million miles (200 million kilometers). Mars won't offer much to a telescopic observer; its tiny gibbous disk will be only seven seconds of arc across by the end of the month.

Jupiter

Our solar system's largest planet is well placed for observing during April. Look for it high up in the southwestern portion of the sky after sunset. Jupiter is moving from Taurus into Gemini where it will be located next month.

In the beginning of the month it shines at -1.7 magnitude and sets after midnight. By month's end, its bright-

Top: Jupiter, Mars and M-35 comprise this shot taken on Sept. 4, 1977. If you look closely at Jupiter, you should be able to see two of its four moons: From left to right are Ganymede (Io and Europa are obscured by the planet's glare) and Callisto. North is at the top. This shot was taken using an 80-200mm Rokkor lens at f/4.5 for one minute at 120mm focal length. High Speed Ektachrome film was used and pushed to ASA 400. Center: Planets, constellations and even our own moon highlight this single photograph. Pictured are the planets Jupiter and Mars, the constellations Auriga, Orion and Taurus, and, of course, the moon. North is to the left; east is at top. This shot was taken on Sept. 4, 1977 using a 24mm Rokkor lens at f/2.8. High Speed Ektachrome film (pushed to ASA 400) was used for the three minute exposure. The "UFO" is a lens flare. Photographs by Mario Mateo. Bottom: Jupiter (in the center) and Mars (to the left) shine through the shimmering curtain of the Aurora Borealis in this picture taken with a 35mm Yashica using High Speed Ektachrome. Photograph by Carlos Pabow.



Upper left: Comet Kohler shines faintly at seventh magnitude in this photograph taken on Nov. 19, 1977. Discoverer Merlin Kohler received the Tuthill comet award for his finding. Photograph by Lester Yuill. Lower left: Jupiter is shown eight days before opposition in this shot taken on Dec. 14, 1977. The photo was taken using the eyepiece projection method with an eight inch Celestron. The exposure was three seconds on SO-410 film at f/131. Photograph by Tom Koed. Right: One of the lesser photographed objects, NGC-7023 in Cepheus, is shown here taken with a 12 inch reflector at f/6, and exposed for 15 minutes on 103aF film. Photograph by Jean-Guy Moreau.

ness decreases 1/10 magnitude to -1.6, and it sets about an hour before midnight. On the 13th the moon and Jupiter will make an attractive pair. Jupiter will be five degrees north of the moon, which will be approaching its first quarter phase. The planet is gradually pulling away from Earth — its distance increases from 492 million miles (787 million kilometers) to 530 million miles (850 million kilometers).

If you turn your telescope toward Jupiter, you'll see a slightly flattened disk 36 seconds of arc in equatorial diameter and 33 seconds in polar diameter. If you're lucky, you may also get to see Jupiter's Great Red Spot.

Saturn

Saturn joins Venus, Mars and Jupiter in the evening sky as the fourth planet that is well placed for observing — high above the southeast horizon at sunset. Like Mars, Saturn has been dimming since it was at opposition in February (magnitude +0.3). During this month it will drop a barely perceptible 1/10 magnitude, from +0.5 to +0.6.

Saturn, located in the constellation Leo, passes overhead at about 8 p.m. and is visible all night until it sets approximately two hours before sunrise. On the 17th, look for the ringed planet five degrees north of the moon, which will be just past first quarter. During the month the planet's distance from Earth will increase from 793 million miles (1.2 billion kilometers) to 832 million miles (1.3 billion kilometers). The ball of Saturn — slightly flattened — will be 19 by 13 seconds of arc. Its ring system will extend some 43 seconds of arc, and at midmonth will be tilted 13 degrees from our line of sight.

Uranus

This may be a good month to observe Uranus, situated in the constellation Libra. The planet won't be at opposition until next month; it already is at maximum brightness (magnitude +5.7) for April.

With a moderate sized telescope (six inch), you should be able to find Uranus easily because it will be near the star Alpha Librae (a double star whose components are separated by about 230 seconds of arc). At the beginning of the month, simply center Alpha, and then wait three or four minutes for Uranus to drift into view. By midmonth you'll only need to wait a minute or two as the planet moves closer to the star. On the 27th, Uranus will be just 1/12 degree north of Alpha. Uranus will be recognizable as a tiny (four seconds of arc) greenish disk, but you won't be able to see its rings.

Pluto

Pluto is at opposition on April 5. The planet is located in the constellation Virgo, six degrees east of Epsilon Virginis and 15 degrees southwest of Arcturus (see this month's Planet Finder for its precise position). At opposition Pluto will be 2.7 billion miles from Earth — 13 million miles closer than its last opposition.

Latest estimates (1977) of Pluto's size indicate that it measures 2,000 miles (3,200 kilometers) in diameter, making it the smallest of the solar system planets — even smaller than our moon! Pluto, at 14th magnitude, is too faint to be seen in small and medium size telescopes.

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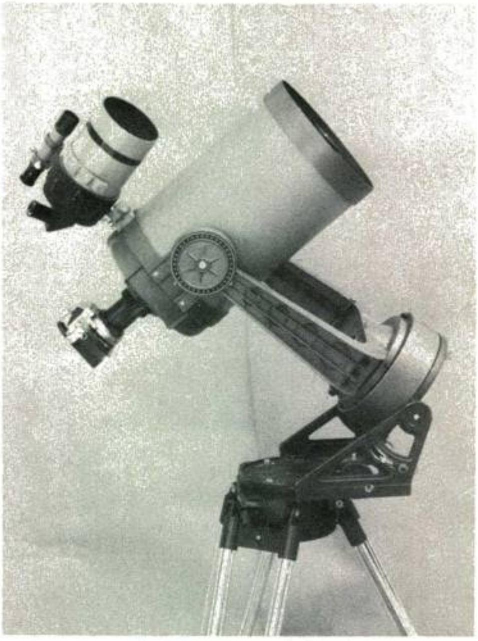

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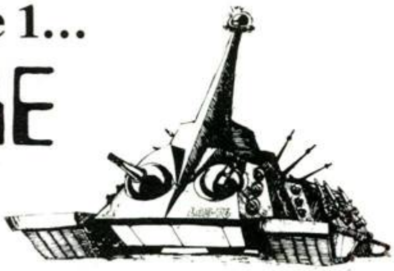

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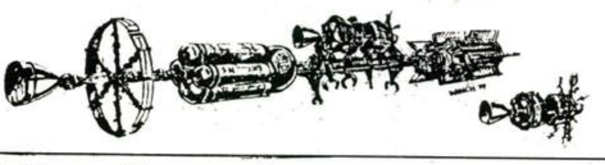

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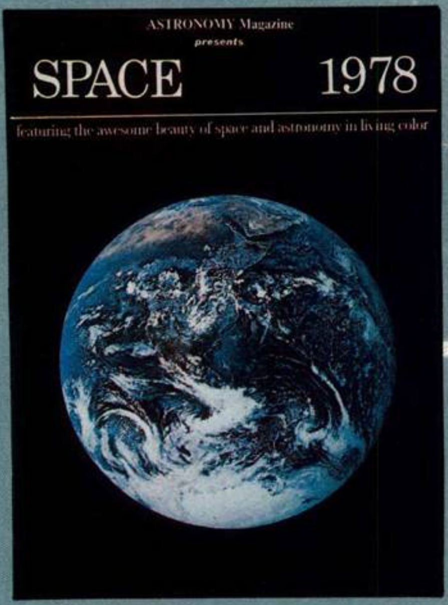
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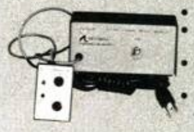

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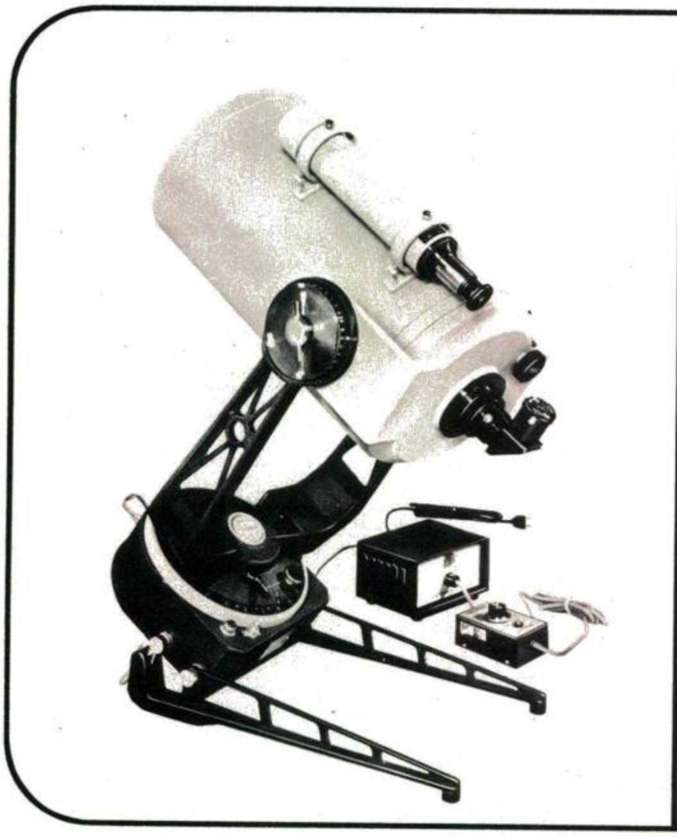

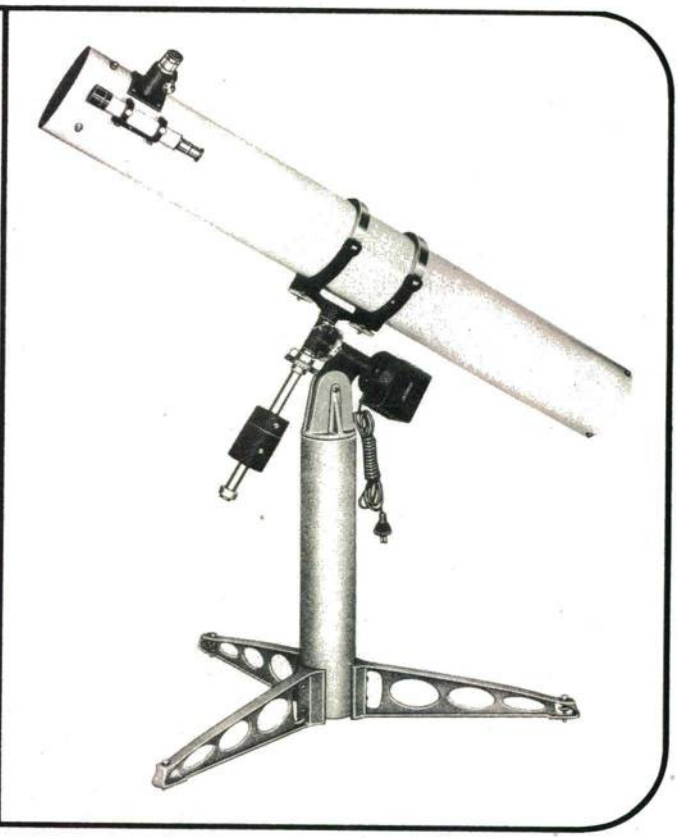

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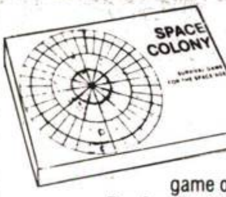

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WANTED — "Atlas Borealis", "Eclipticalis", "Australis". Hardcover flat editions in good condition. Also astronomy, optics and scientific technical publications. Write Phillip N. Davis, Box 4650, Tulsa, OK 74104.

WANTED — Correspondence with persons interested in astronomy, science fiction, foreseeable *interstellar travel.* Also wish to join any type of astronomy club in south Georgia area. Write Philip Mellor, 130 St. Clair Dr., St. Simons Island, GA 31522.

WANTED — Pressbooks and stereo slides from 3-D films of the 1950s. Contact Albert Della Malva, 81 Congress St., Jersey City, NJ 07307. Phone (201) 659-3640.

WANTED — Laser, monochromator or laser spectrographic system and components for reasonable cost to high school. Send photos, diagrams, information, price to David Digioia, Marquette H.S. Science Club, 306 W. 10th St., Michigan City, IN 46360. Phone (219) 879-3902.

WANTED — Navigational data, courses, distances, etc. from episodes, magazine articles, papers, your ideas/theories concerning arrangement of "Star Trek's" universe. Wish to compile astronomically correct map of Federation and Milky Way. Write Tim Farley, 3001 Wendover Rd., Valdosta, GA 31601.

WANTED — UFO magazines, newspaper articles from 1965 to 1975. Will pay reasonable price. Send list, prices to Guillermo Gonzalez, 5825 N.W. 112th Terr., Hialeah, FL 33012.

WANTED — ASTRONOMY back issues: October 1973 (Vol. 1, No. 3), November 1973 (Vol. 1, No. 4), December 1973 (Vol. 1, No. 5), January 1974 (Vol. 2, No. 1). Write Todd Delaney Gruber, 3134 North Meadow Ct., N.E., Marietta, GA 30062.

WANTED — Correspondence with amateurs interested in radio astronomy and astronomically oriented computer applications. Write Darrell Hancock Jr., 1878 Bahama Rd., Lexington, KY 40511.

WANTED — Antique or out-of-print books, star charts, maps, any other items pertaining to astronomy. Write Chris Heath, 5145 Valencia Dr., Orange, CA 92669.

WANTED — Reports of encounters, sightings or theories of UFOs and their origin. Also physical evidence (photographs, etc.) if possible for future book. Names, places kept confidential if requested. Write Ray Swartz Jr., 3024 Woodlawn, Walled Lake, MI 48088.

WANTED — Space posters of any kind. Contact David Tropkin, 4125 Oxnard Circle, Las Vegas, NV 89121. Phone (702) 458-8496; no collect calls, please.

WANTED — 35mm SLR camera for astrophotography; must have removable lens. Will pay shipping. Write Robert Vogtli, 2016 St. Nazaire, Homestead Air Force Base, FL 33039.

WANTED — ASTRONOMY back issues: September 1973 through February 1974; May, June 1974; August 1974 through April 1975; June 1975. Must be in good condition. State prices. Write Barry Rappaport, 156 Bradford St., New Providence, NJ 07974.

WANTED — Correspondence with persons (ages 18 to 25) interested in performing simulated unmanned comet exploration mission as described in ASTRONOMY, May 1975, page 28. Send ideas to David Rutledge Shaw, 271 Hume Dr., London, OH 43140.

WANTED — Correspondence with persons (preferably female) interested in space colonization/exploration, astronomy, "hard" science fiction (a la Clement), philosophy (Ayn Rand), nuclear weapons technology (Taylor). Write Randall Sherwood, 118 Laidlaw St., Cannington, Ontario, CANADA L0E 1E0.

WANTED — October 1973 issue of ASTRONOMY to complete set. State condition, price. Write Arlene Joseph, Pascack Hills High School, Grand Ave., Montvale, NJ 07645.

WANTED — October and December 1973 issues of ASTRONOMY. Must be in good condition. Please state price. Write Robert D. Joy Jr., R.R. #2, Box 212-B, Sherman, CT 06784.

WANTED — Comic books popular among collectors. Send list with name, issue number, condition. Will make offer. Write David and Bill Lewis, 2519 Applelane Dr., Kalamazoo, MI 49008.

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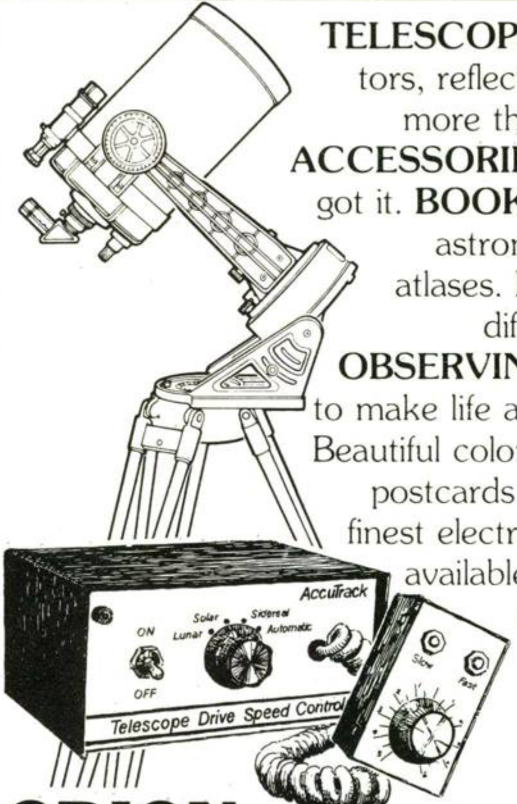

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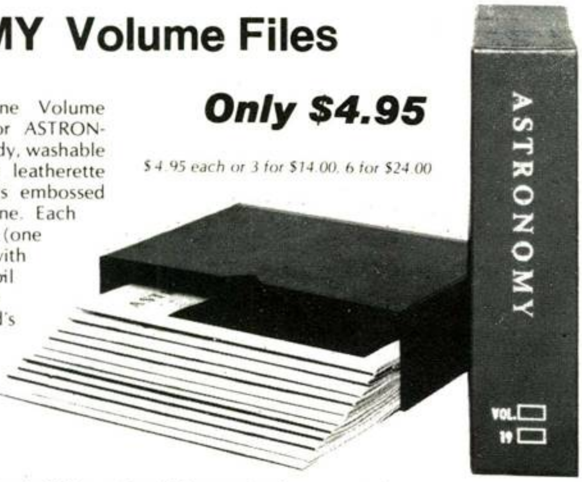

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WANTED — Good quality B&W or color slides (2" x 2") of star fields, including parts of or whole constellations. Will pay $1.00 per slide after verification. Write John Marshall, 1 Gracie Terrace, Apt. 7D, New York, NY 10028.

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POSITION WANTED — Planetarium position. Am 23; have B.S. in physics, Mississippi secondary teaching permit. Background in astronomy, astrophotography; active in promoting mid-south amateur astronomy. Resume on request. Write Wayne R. Coskrey, 206 Bridle Path, Starkville, MS 39759.

ANNOUNCEMENT — Amateur Astronomy convention, May 20-21, Rogerson Center for Arts and Sciences, Binghamton. Main speaker: Dr. Frank Drake, director, Arecibo Observatory. Solar observing, Stonehenge lecture, planetarium show, more. For details, write Broome County Astronomical Society, 30 Front St., Binghamton, NY 13905.

ANNOUNCEMENT — The Columbus (Ohio) Astronomical Society meets every second Saturday from September to May at the Battelle Memorial Institute, Room G, 8 p.m. For more information, contact Robin de Santos, (614) 237-0954, or Steve Hipes, (614) 237-5542.

ANNOUNCEMENT — Chagrin Valley Astronomical Society meets 1st Sunday each month (3 p.m.) at St. Rita's Church, Family Room, 32815 Linden Dr., Solon, Ohio. Persons interested in astronomy welcome. Write C.V.A.S., Box 11, Chagrin Falls, OH 44022. Or call Earl at (216) 729-4744.

ANNOUNCEMENT — Communications invited on feasibility of workshop, observatory on 10 acre site in Deptford (near Woodbury, N.J.). Program suggestions could include solar energy prototypes along with monitoring sun with optical, R.F. equipment. Write Warren Felton, 445 S. Highland Rd., Deptford, NJ 08096.

ASTRO-NEWS

Latest News From the World of Astronomy

Shuttle Payloads Offer Wide Variety of Options

"How much will it cost to fly on the Space Shuttle?"

This question is being asked with increasing frequency, and is a question to which NASA is paying a great deal of attention. NASA plans to begin Shuttle operation flights in 1980.

The answer is anywhere from less than $10,000 to more than $21 million — depending on the weight and volume of the cargo, whether it's on a reservation or standby basis, and what optional services are desired.

What about passengers?

"No, not yet," said Chester M. Lee, operations director for NASA's Space Transportation Systems. "Nonastronaut payload specialists may fly on some missions to conduct experiments and operate equipment, but we're not ready to book tourists yet."

According to Lee, the Space Shuttle will carry as many as seven people on a flight. Three will be crew members (NASA astronauts) — pilot, co-pilot and mission specialist. The other four will be payload specialists, assigned by the customer for the mission.

At the low end of the fare structure is the so-called "get-away special" which permits an individual or organization to fly a payload in the Shuttle on a space available basis for $10,000 or less. To qualify for this low fee, the proposed payload must involve research, weigh less than 200 pounds, have a volume of less than five cubic feet and be self contained. Any services would cost extra.

The $21 million fare is for using the full capacity of the Space Shuttle on a reservation basis by non-U.S. government customers.

In between are charges for customers sharing the Shuttle flight with other customers, customers willing to fly on a standby basis, and customers who have made a substantial investment in the Space Transportation System development. This latter category includes the European Space Agency, its member nations and Canada. ESA is developing the Spacelab to be carried in the Shuttle, and Canada is developing the remote manipulator system which will be used in the Shuttle.

Lee said the pricing policies are designed to encourage full use of the Shuttle by making the charges economically attractive while recovering the total operating costs incurred by NASA. For commercial and foreign users, there will also be a use fee covering depreciation of facilities and equipment, and amortization of orbiters.

"After three years of operation we plan to re-examine prices to determine whether operating costs are being recovered and to make adjustments if necessary," Lee said. The policy also as an escalator clause to account for inflationary increases.

There are reduced price incentives for payloads having exceptional merit, and added charges for short-term callups, postponements or cancellations. Lower rates are offered for standby payloads, floating launch date options and reserving space on future missions.

"Our policies also make it possible for several users to share a Shuttle flight, with the price of the shared flight being a fraction of the cost of the total mission," Lee said. Charges for shared flights will be based on the size of the payload and its destination.

The NASA policy covers subletting of space in the Shuttle and includes standard services such as design and safety reviews, flight planning, provision of a three man crew and transmission of payload data. Optional services available for additional cost include special crew training, upper stages and services, special mission kits, revisit and retrieval of satellites and special equipment.

The Space Shuttle is a reusable spacecraft that will make possible frequent and routine access to space at costs less than if the present expendable launch vehicles were used.

The Shuttle Orbiter payload bay, or cargo compartment, will carry loads weighing as much as 65,000 pounds and as large as 15 feet (4-1/2 meters) in diameter and 60 feet (18 meters) long.

The first Space Shuttle Orbiter, named Enterprise, is undergoing approach and landing tests at NASA's Dryden Flight Research Center, Edwards air Force Base, Calif. The first orbital flight test is scheduled for launch from NASA's Kennedy Space Center in 1979, and the first operational flight is set for 1980.

NASA Inquiry Board Reports on Launch Failures

A NASA Board of Inquiry has issued its final report on the failure of an Atlas-Centaur launch vehicle. Launched on Sept. 29, 1977 from NASA's Kennedy Space Center, the vehicle, with an Intelsat IV-A spacecraft aboard, was destroyed 55 seconds into the flight.

The Board of Inquiry determined that the cause of the Atlas-Centaur failure was a rupture in the high-pressure "omega joint" in the Atlas stage booster gas generator discharge line. The fault occurred as a result of corrosion following carbon contamination during brazing in the production cycle.

Since the fault was a processing failure and not a design problem, the joints on all other completed vehicles were tested. All vehicles now at the Kennedy Center passed the test, but a few omega joints in the factory were corroded or questionable, and are being replaced.

In the future, fabrication of this joint and others like it using the same stainless material will be processed in a manner which prevents contamination.

Scientists Selected for Space Telescope Project

Eighteen people have been tentatively selected by NASA to participate in the design and early operational phases of the Space Telescope project.

Scheduled to be launched into Earth orbit in 1983 by the Space Shuttle, the 10 ton (9,100 kilogram) observatory will make astronomical observations deeper into space and with more detail than has ever before been possible.

The Space Telescope should aid in solving some of the mysteries relating to the structure, origin, evolution and energy processes of the universe, which could never be accomplished with observatories below the obscuring veil of Earth's atmosphere.

Scientists have been chosen to head teams and to participate individually in the following categories:

Investigations Definition Teams: These teams consist of principal investigators, co-investigators and supporting staffs who will design and develop the focal plane scientific instruments. They will also carry out major scientific investigations.

Individual Co-Investigators are scientists who had not been affiliated with an investigation definition team prior to selection, but who will now be assigned to a team.

The Astrometry Science Team will be responsible for assuring that the fine guidance system will adequately perform astrometric functions as required.

U.S. Members of European Space Agency Faint Object Camera Instrument Science Team: The two U.S. members chosen will represent the American astronomical community.

Telescope Scientists: Two scientists have been chosen with strong backgrounds in optical instrumentation. They will be responsible for interpreting the scientific performance requirements in terms of telescope design specifications.

The Data and Operations Team Leader will lead a team of representatives appointed by each principal investigator to review or establish requirements and specifications for instrument control systems, flight operations and ground data handling systems.

Interdisciplinary Scientists will give breadth to the guidance of the Space Telescope project beyond the concerns of the individual principal investigators and technical specialists. The four chosen will be responsible for a broad scientific overview of the observatory's development.

With the Space Telescope, astronomers should be able to observe some 350 times the volume of space that can be seen now with the largest ground based telescope.

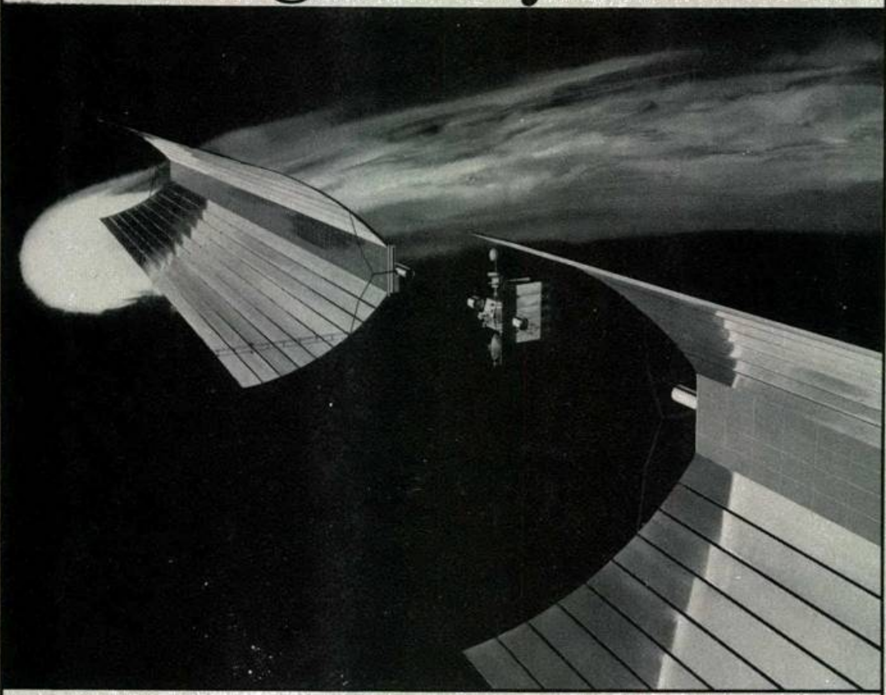
Once placed in orbit, the telescope will be operated remotely from the ground. However, it will be designed to permit maintenance, to allow the change of instruments by a spacesuited astronaut, and to be retrievable by the Space Shuttle for overhaul and subsequent relaunch. These features should extend the life of the Space Telescope to over 10 years.

The eight foot (2.4 meter) diameter Space Telescope will be capable of accommodating five different instruments at its focal plane. It will orbit Earth at an altitude of approximately 310 miles (500 km), above the obscuring effects of the atmosphere.

The total planned payload of five instruments consists of two cameras, two spectrographs and a photometer. The Faint Object Camera (provided by European Space Agency) and the Wide Field Camera are distinguished by their

Scientists *continued on page 69*

Chasing Halley's Comet



Here is an artist's concept of the Ion Drive Spacecraft which has been proposed for chasing and studying Halley's Comet when it approaches Earth in 1986. According to NASA, the ion drive propulsion system was selected over the solar sail concept as the vehicle for interplanetary automated shuttle use within the solar system in the 1980s and beyond.

Both the ion drive and solar sail concepts were studied and evaluated in various configurations for a year by scientists and engineers; the ion drive was chosen on the basis of lower risk and greater future growth potential.

An ion drive spaceship employs a cluster of mercury ion engines and uses power generated by large solar cell panels that convert sunlight into electricity. These panels (pictured above) include large scooped reflectors that focus solar radiation on the central bank of silicon solar cells.

Mercury ion rockets for solar electric propulsion have been under development for a decade by NASA. In 1969, ion rocket engines were placed in Earth orbit as part of a program titled the Space Electric Rocket Tests; these forerunners of the ion drive spacecraft are still operated regularly in space.

If NASA selects this mission from among several options, the first use of ion drive propulsion could be for a Halley's Comet rendezvous in 1986. The ion drive spacecraft would be designed for launch from the Space Shuttle in late 1981 or early 1982 NASA artwork.

Cosmic Background Radiation Indicates Milky Way Traveling 1 Million M.P.H.

The Milky Way galaxy has been found to be traveling through the universe at more than a million miles per hour.

Scientists Richard Muller, George Smoot and graduate student Marc Gorenstein of the Lawrence Berkeley Laboratory made this discovery using data from radio equipment aboard an Ames Research Center U-2 jet. The extremely sensitive radio equipment was used to study the cosmic microwave background (radiation) which, according to the scientists, was left over from the big bang.

The big bang — the event that initially formed the universe — has always been assumed to have been an explosion of the most powerful force imaginable. Upon measuring the radiation, the research team found its expansion uniform, with matter and energy being equally distributed.

According to the research team, "Our measurements give a picture of an extremely smooth process." They feel the big bang was a very smooth, serene event. "Either conditions before the beginning were very regular, or processes we don't yet know about worked to make the universe extremely uniform. The radiation left over from the universe-forming event about 15 billion years ago is so uniform that it provides a universal reference for measuring this motion," Gorenstein said. This universal reference was used to determine how fast our Milky Way galaxy is traveling.

The sensitive radio equipment used was designed and operated by the University of California at Berkeley.

Scientists

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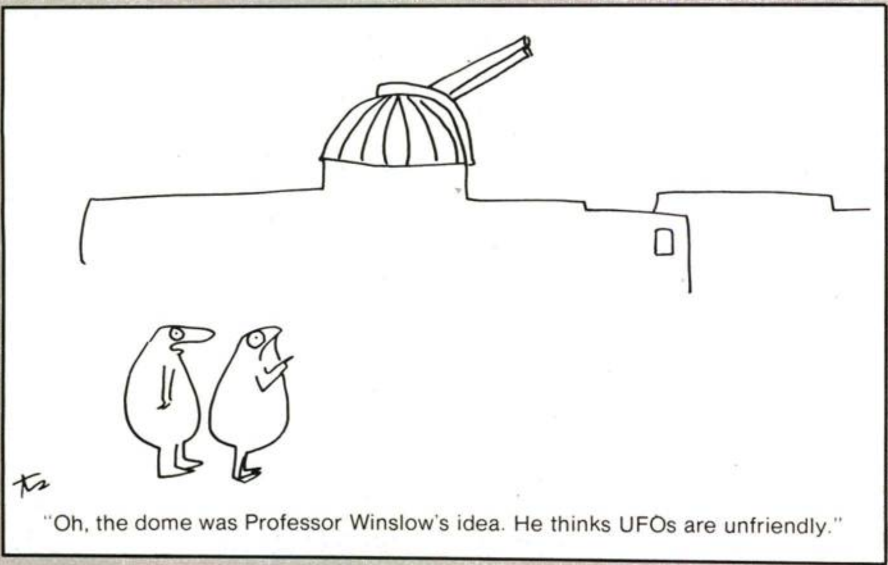
fields of view, spatial resolution and wavelength range. Both instruments cover the ultraviolet and blue regions of the spectrum. The Wide Field Camera covers a field at least 40 times larger, but with a resolution degraded by a factor of two to four.

The two spectrographs provide a wide range of resolutions which would be impossible to cover in a single instrument. Only the Faint Object Spectrograph covers the visible and red regions of the spectrum.

The fifth instrument is a simple, singel channel photometer which can be used for calibrating the other instruments and for very high speed photometry. By operating while other instruments are observing, this instrument can also collect information on the brightness of the galactic background.

A Space Telescope Science Working Group will provide scientific guidance to the project. The group will be composed of the various team leaders, the two telescope scientists, the interdisciplinary scientists and appropriate project personnel.

NASA's Marshall Space Flight Center will have overall management responsibility for the Space Telescope. NASA's Goddard Space Flight Center will be responsible for managing the development of the scientific instruments and for the operational aspects of the observatory. The European effort will be directed by the European Space Technology Center at Noordwijk in the Netherlands.



"Oh, the dome was Professor Winslow's idea. He thinks UFOs are unfriendly."

BRIEFS

● Landsat 1, the world's first spacecraft designed to monitor and discover Earth's natural resources, was retired by NASA in mid-January after operating 5-1/2 years in outer space. Designed with a life expectancy of only one year, Landsat 1 was launched in 1972. The spacecraft "more than achieved its goals, in fact beyond any stretch of the imagination," said Ron Browning, Landsat project manager.

● A new device to reduce and regulate pressure inside the eye during glaucoma surgery has been developed by NASA's Lewis Research Center and the Kresge Eye Institute. The new system provides continuous recording of pressure inside the eye during surgery. The device is based on fluid systems and components technology developed by NASA.

● A concept fostered by a NASA scientist for studying x-ray sources in space has led to development of a hand-held x-ray instrument, the Lixiscope (for Low Intensity X-Ray Imaging Scope), which produces an instant image with a small source of radioactive material.

Powered by a single pen size battery, the prototype model exhibits high potential for screening and other uses in medicine, dentistry and areas of industry. Potential applications of the portable instrument range from examination of a football player's possible bone injury on the field to detection of welding defects or gas leaks in pipes.

● In the name of science, American astronomers have taken a stand on women's rights. Dr. Margaret Burbridge, president of the American Astronomical Society, announced in mid-January that the group will no longer hold meetings in states which have not yet ratified the Equal Rights amendment. It will not affect any AAS meetings already scheduled through 1980, which will be held in what Burbridge referred to as "enlightened states".

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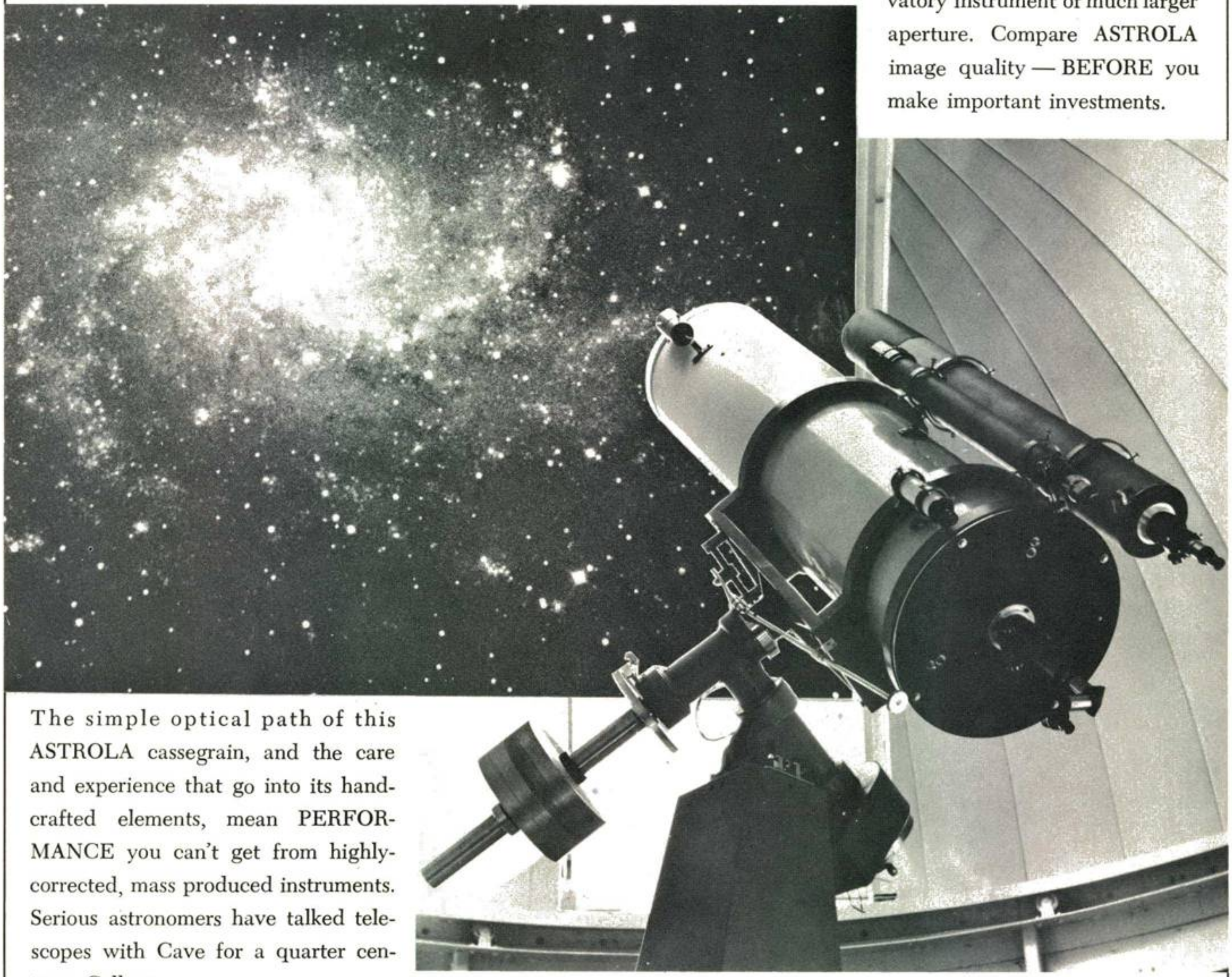

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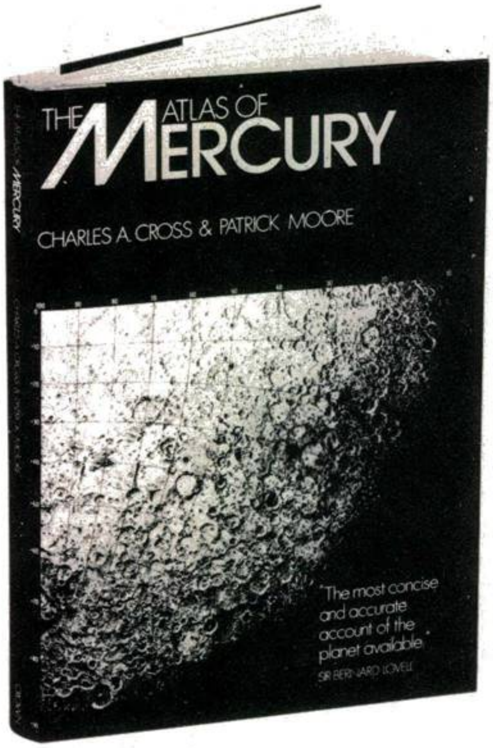
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STAR DOME

APRIL

by
James Mullaney and Henry J. Phillips

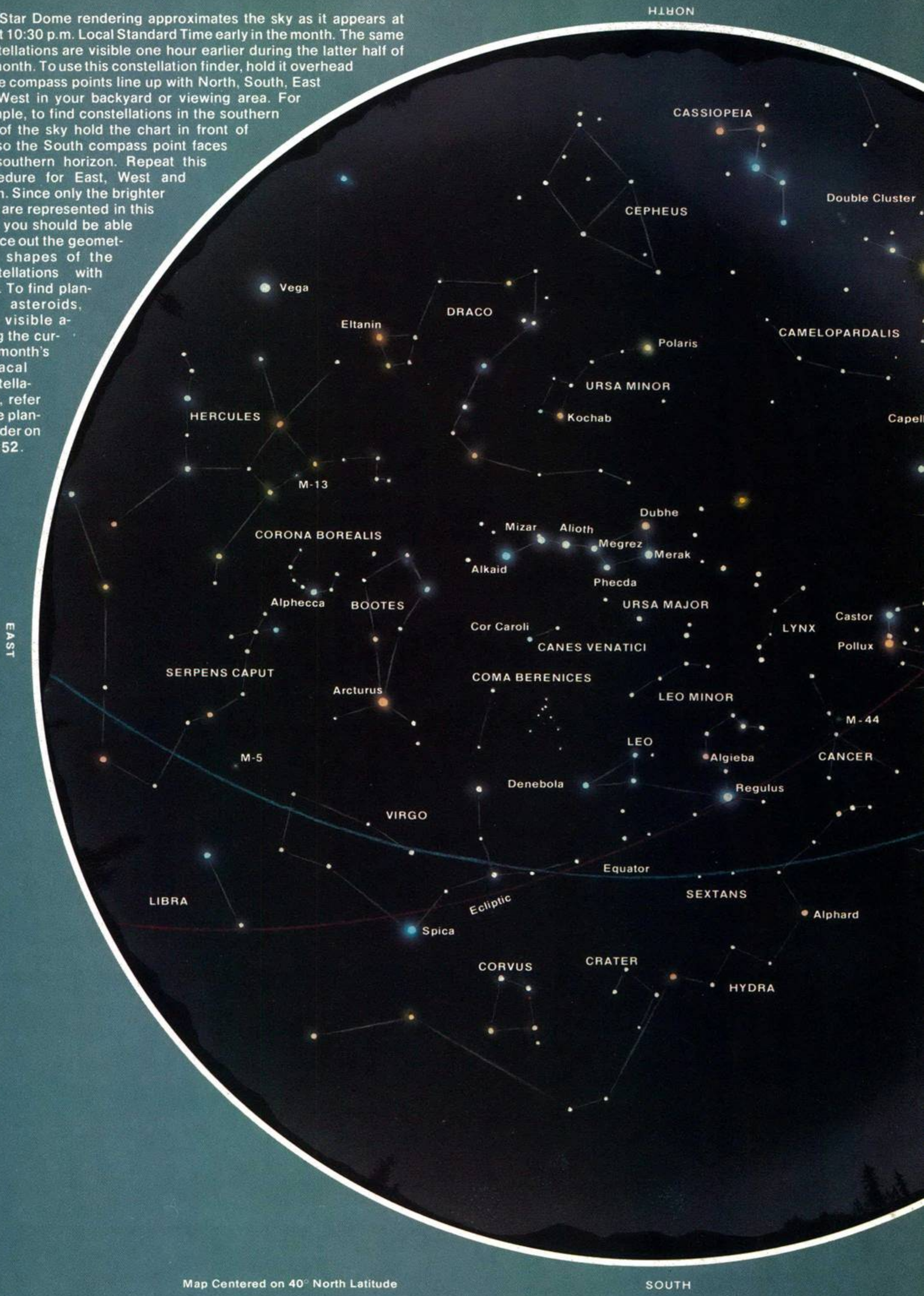
This month's Close-Up region is not a constellation in itself, but an area overlapping parts of two neighboring groups (Coma Berenices and Virgo), in which deep sky objects are concentrated with unusual density. As in past Star Domes where the Close-Up region was unusually rich, we've devoted an extra amount of space to that section this month.

We'll devote our introductory portion this month to Coma Berenices and its accompanying myth. Although Coma is not one of the oldest constellations, it dates from the late Greek era; its name means "Berenice's hair". But who was Berenice, and how did her hair get immortalized in the sky?

Berenice was the wife of Euergetes, an Egyptian king who lived about 250 B.C. When her husband went off to one of his wars, Berenice, fearing for his return, visited the temple of Venus and promised the goddess that she would sacrifice her long, beautiful hair if her husband returned safely. She must surely have been among the least vain of queens to make such a vow — or else she really didn't expect Euergetes to come back. Return he did, however, and off came the tresses. History doesn't record Euergetes' reaction, but he was undoubtedly much surprised — rather like coming home expecting to be greeted by Farrah Fawcett-Majors and finding Telly Savalas instead!

The hair was ceremoniously presented to the altar of Venus (didn't Berenice think of trying to palm off an old wig?), from which it was promptly stolen (probably by a destitute hair stylist). The queen, of course, was un-

This Star Dome rendering approximates the sky as it appears at about 10:30 p.m. Local Standard Time early in the month. The same constellations are visible one hour earlier during the latter half of the month. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the constellations with ease. To find planets, asteroids, etc., visible among the current month's zodiacal constellations, refer to the planet finder on page **52**.


NORTH
CASSIOPEIA
CEPHEUS
Double Cluster
Vega
DRACO
Eltanin
CAMELOPARDALIS
Polaris
URSA MINOR
HERCULES
Kochab
Capell
M-13
Dubhe
Mizar
Alioth
Megrez
Merak
CORONA BOREALIS
Alkaid
Phecda
Alphecca
BOOTES
URSA MAJOR
Castor
Cor Caroli
LYNX
EAST
CANES VENATICI
Pollux
SERPENS CAPUT
COMA BERENICES
Arcturus
LEO MINOR
M-44
LEO
M-5
Algieba
CANCER
Denebola
Regulus
VIRGO
Equator
LIBRA
SEXTANS
Ecliptic
Alphard
Spica
CORVUS
CRATER
HYDRA
SOUTH

Map Centered on 40° North Latitude

Algol
PERSEUS
Pleiades
TAURUS
Hyades
AURIGA
Aldebaran
M-35
GEMINI
Betelgeuse
ORION
WEST
CANIS MINOR
M-42
Procyon
MONOCEROS
Sirius
M-41
CANIS MAJOR
PUPPIS

Map by Adolf Schaller

consolable, no doubt feeling her sacrifice had been in vain. But the quick-thinking temple priest comforted Berenice (and possibly saved his own neck in the process) by convincing the royal couple that the royal hair had been placed in the heavens by Venus herself, as a reward for the queen's unselfishness. That night he pointed out the faint cluster of stars that make up our present day constellation and told the king and queen that the hair had been transformed into these stars. Obviously, Berenice hadn't been much of a stargazer or she would have seen through the trick at once — but she was satisfied. (One wonders how long it took to satisfy her with these stars and not, say, those of Orion instead.)

So that's how a head of hair found its way into the sky, remaining there to this day. Could the many galaxies within its borders be considered dandruff?

Close-Up

Realm of the Galaxies

"A wonderland surpassing the dreams of fiction writers is hidden in the Coma-Virgo region of the sky, between the stars Vindemiatrix and Denebola." So claimed noted California observer Leland Copeland nearly three decades ago in a classic guide to the amazing Realm of the Galaxies.

Vindemiatrix is Epsilon (ϵ) Virginis — the famed Roman vintage star — while Denebola is Beta (β) Leonis, in the lion's tail. These starry beacons mark the location of the largest concentration of "island universes" in the heavens available to stargazers. The colossal Virgo cluster spreads northward into Coma Berenices — where we find showpieces like M-64 (the Black-eye galaxy) — and as far south as Spica and M-104 (the Sombrero galaxy). In its dense core, however, within the rectangular expanse of sky bounded by declination + 10 degrees to + 20 degrees and right ascension 12 to 13 hours, are so many galaxies that it's difficult *not* to see one or more in the field wherever you look.

Our detailed map hints at the vast swarm of galaxies to be found, and those shown are only the brighter of the more than 3,000 cluster members! You can spend many happy evenings exploring this amazing extragalactic hunting ground (or "celestial forest", as Messier authority Holyoke called it). On a dark transparent night, all the objects plotted lie within reach of a six inch telescope — so many, in fact, that identification becomes a very real problem. In this sense, at least, smaller apertures have an advantage, as they reveal only the brighter units.

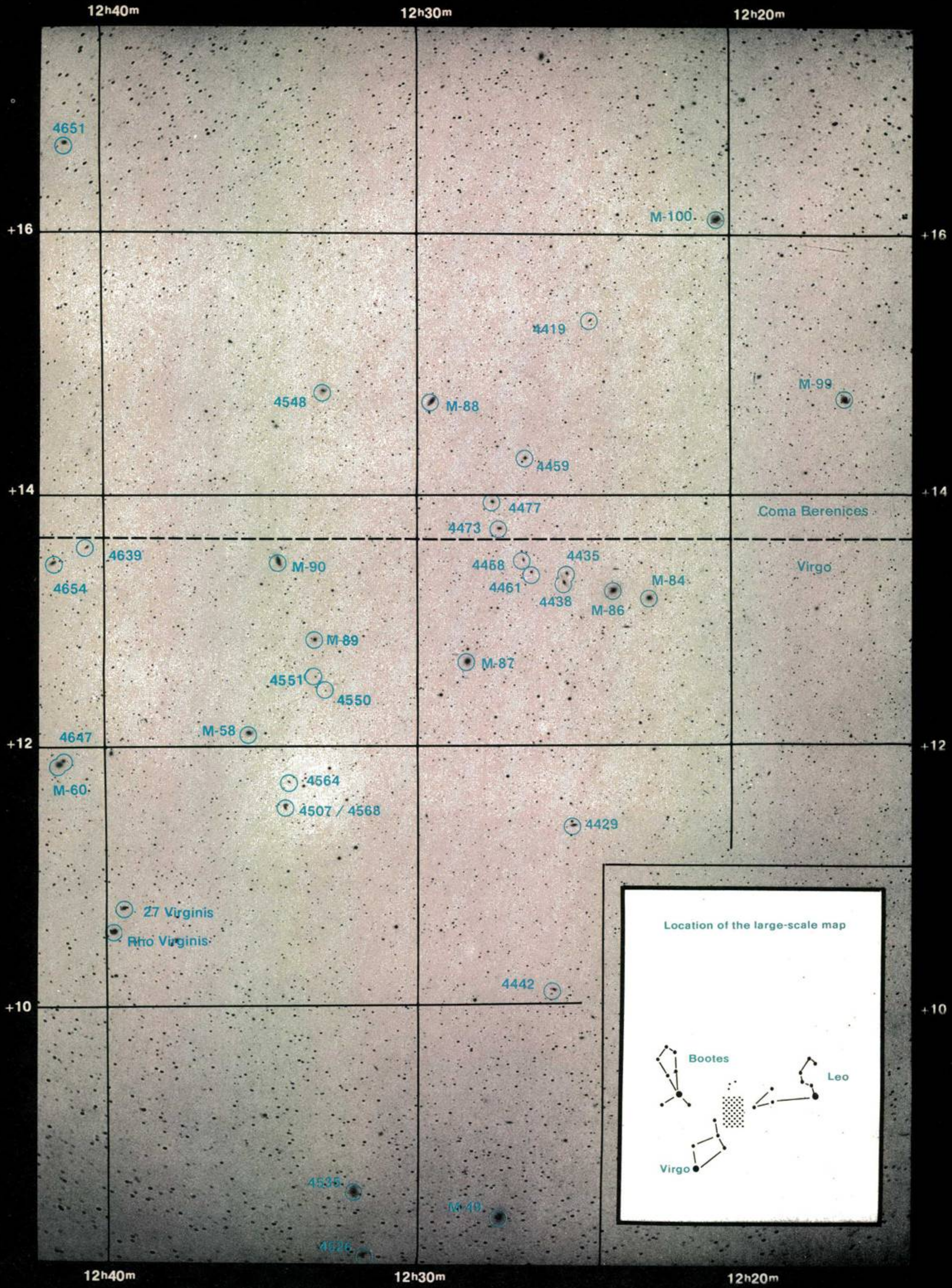
Smyth called this area "A wonderfully nebulous region . . . in which several of the finest objects of Messier and the Herschels will be readily picked up by the keen observer in extraordinary proximity." Webb's assessment appeared in his introduction to Virgo, written from the perspective of more than a century ago: "A constellation especially remarkable, for those possessed of adequate optical means, on account of the wonderful nebulous region, in which a far greater number of these extraordinary bodies are accumulated than in any other equal area of the heavens: William Herschel having detected within its boundaries no less than 323. Few of them, however, are individually interesting; it is the mysterious thronging together of these objects, whatever may be their nature, that opens such a field for curiosity. They are in general so much alike, that I have only adduced a few as specimens."

Webb's approach has been followed by virtually all observers since his time, and few have ventured to make a detailed study of the individual objects themselves as seen at the eyepiece. Indeed, famous observers — including Pickering, Olcott and Brown — appear to have avoided this congested area completely! Olcott, for example, merely stated in his classic observing guide: "It is not possible to do more than glimpse the nebulae that feature this constellation . . . ."

In this respect, observers of the past were wrong, for despite their great numbers, each galaxy has a "personality" all its own. No two are exactly alike — especially if you view them in eight inch and larger instruments. Our table of selected objects contains more than two dozen of the brightest specimens of this great cluster, all of which can be glimpsed in a four inch telescope on a good night. Exact identification of each object will require some patience at the eyepiece, since several ghostly glows can often be seen in the same low power field of view! Careful attention to our touring map will be necessary, using those stars shown as guideposts shining along the way. In addition to the usual technique of star hopping, some "galaxy hopping" will also be required!

Holyoke commented: "The observer who would identify the whole Messier catalog and who holds out through the Coma-Virgo galaxies can feel that he 'has it made'. Nothing else will tax him as much as this (region)."

Before commencing our survey, let's take a closer look at the table itself to see what can be gleaned from its neatly compacted data. Most obvious is the fact that Messier did a pretty good job of picking up the brightest cluster members with his rudimentary telescopes. Indeed, you can make a fair


12h40m
12h30m
12h20m
4651
M-100
+16
+16
4419
M-99
4548
M-88
4459
+14
+14
4477
Coma Berenices
4473
4639
4654
M-90
4468
4435
4461
4438
M-84
M-86
Virgo
M-89
M-87
4551
4550
M-58
4647
+12
+12
M-60
4564
4507 / 4568
4429
27 Virginis
Rho Virginis
Location of the large-scale map
4442
+10
+10
Bootes
Leo
Virgo
4535
M-49
4526
12h40m
12h30m
12h20m

Photograph by E.E. Barnard, Yerkes Observatory/Map by Richard Berry guess about the effective limiting magnitude of his instruments.

A point of interest here is that the elliptical galaxies are in general smaller, but brighter, than the spirals. Such differences are real and a property of the objects themselves, since all members of the Virgo cluster lie at roughly the same distance from us — 15 million light-years, or nearly 90,000,000,000,000,000,000 miles!

One final point to keep in mind as you embark on far-flung explorations: You must "see" with your mind as well as your eyes to appreciate the significance of the varied scenes unfolding before you. As Copeland so eloquently expressed it: "Why should we bother to look at these galaxies, which are often hardly discernible in amateur telescopes? Not for what they seem to be, but for what they are: Each is a distant Milky Way, seen by light million of years older than prehistoric man. They can help us gain true perspective — we and our world are the minitiae and curiosa — galaxies are the grand realities. Thoughts like these explain why some (of us) pass leisure hours hunting for tiny, misty spots . . . . For us those hazy blobs and splinters of light are among the major details of existence."

NGC-4147

Our first offering is not a galaxy at all, but rather a kind of "cosmic interloper" into the Realm of the Galaxies! This is tiny NGC-4147, a globular cluster in our own galaxy shining at magnitude 9.4 and measuring only 1.7 minutes of arc in diameter. It lies clear of the main galactic cloud, 1/2 degree north and three degrees west of the star 11 Comae.

The NGC records this object as a "Globular cluster of stars. Very bright, pretty large, round, gradually brighter in middle, well resolved, clearly consisting of stars." NGC-4147 — like virtually all the non-Messier objects here — was discovered by Sir William Herschel, and the NGC description is essentially his impression as seen in his large metal mirrored reflectors. In a three or four inch scope at 45 power, it looks like a fuzzy star. A six inch at 100 power or more reveals its glittering hosts of suns using averted (side) vision, in striking contrast to the unresolved gossamer glows next to be encountered.

M-85

Just a degree east and slightly north of 11 Comae, on a line to 24 Comae (a superb orange and blue double star for small telescopes), lies M-85 — one of the more prominent residents of this thrilling region. It is an elliptical system measuring two minutes in diameter and glowing at magnitude 9.3.

Holyoke described M-85 as a "small oval . . . rather easy for a three inch . . . as it is quite bright", and Muirden saw it as a "small nebulosity with a bright, almost stellar, central condensation . . . a ninth magnitude star following." The NGC gives "very bright, pretty large, round, brighter in middle, star north preceding". Webb regarded this object a "fair specimen of the many nebulae in this region". A faint spiral (NGC-4394) is situated just east of M-85 in the same low power field.

M-98, M-99, M-100

Proceeding southward, we find three Messier galaxies scattered about the star 6 Comae — all within reach of a four inch refractor. M-98 is closest to the guide star, positioned less than one degree west of it. A 10.7 magnitude edge-on spiral, it measures some two by eight minutes of arc in size. Muirden noted it as faint and elongated in an east-west direction. Holyoke stated that its elongated form is very apparent in a six inch reflector at 75 power, and contrasts with the rounded ones of M-99 and M-100 nearby. Webb saw it as a "long ray", while the NGC gives "bright, very large, very much extended in position angle 152 degrees, very suddenly very much brighter in middle".

M-99 lies a degree southeast of 6 Comae. It is a 10th magnitude spiral four by five minutes in size, described as "large and pale" by Muirden. The NGC considers it "Remarkable — very much so. Bright, large, round, gradually brighter in middle, mottled." (Mottling is a peculiar property of certain spiral galaxies reported by many visual observers, in contrast to the "smooth" appearance of ellipticals. For example, the late John Mallas, a well-known deep sky observer from California — in a survey of more than 800 galaxies with a four inch refractor — noted many spirals as having a granular or sparkling texture.)

M-99 was one of the few objects in this region recorded by Barns, who saw it as "Bright, circular, nucleus uncondensed . . . . Holds attention." Lord Rosse called this a "wonderful spiral" and noted three "branches" or arms as seen in his 72 inch metal mirrored reflector.

The third member of the trio is M-100, a 10.6 magnitude spiral about two degrees northeast of 6 Comae on a line to 24 Comae. It appears as a circular nebulosity about four by five minutes in size with little central condensation. The NGC also rates this object as "remarkable — very much so", and describes it as "pretty faint, very large, round, pretty suddenly brighter in middle, mottled nucleus".

Selected Objects — Realm of the Galaxies

Object	Type	Mag.	Size	R.A. (1950)	Dec.
* NGC-4147	GC	9.4	2'	12^h08^m	+18°49'
* M-98	Sp	10.7	2'x8'	12^h11^m	+15°11'
NGC-4216	Sp	10.4	1'x7'	12^h13^m	+13°25'
* M-99	Sp	10.1	4'x5'	12^h16^m	+14°42'
* M-100	Sp	10.6	4'x5'	12^h20^m	+16°06'
* M-84	El	9.3	1'x2'	12^h23^m	+13°10'
* M-85	El	9.3	2'	12^h23^m	+18°28'
* M-86	El	9.7	1'x2'	12^h24^m	+13°13'
NGC-4435	El	10.3	1'	12^h25^m	+13°21'
NGC-4438	Sp	10.8	3'x8'	12^h25^m	+13°17'
NGC-4450	Sp	10.0	3'	12^h26^m	+17°21'
NGC-4459	El	10.9	1'	12^h26^m	+14°15'
NGC-4442	El	10.8	1'x2'	12^h26^m	+10°05'
NGC-4473	El	10.1	1'x2'	12^h27^m	+13°42'
NGC-4477	Sp	10.7	2'	12^h28^m	+13°55'
* M-87	El	9.2	2'	12^h28^m	+12°40'
NGC-4478	El	10.9	1'	12^h28^m	+12°36'
* M-88	Sp	10.2	2'x6'	12^h30^m	+14°42'
NGC-4548	BSp	10.8	3'x4'	12^h33^m	+14°46'
* M-89	El	9.5	1'	12^h33^m	+12°50'
* M-90	Sp	10.0	2'x8'	12^h34^m	+13°26'
* NGC-4567-68	Sp-Sp	11-?	2'-2'x4'	12^h34^m	+11°32'
* M-58	Sp	9.2	4'	12^h35^m	+12°05'
* M-59	El	9.6	2'x3'	12^h40^m	+11°55'
* M-60	El	8.9	2'	12^h41^m	+11°49'
NGC-4660	El	10.9	1'	12^h42^m	+11°26'
* NGC-4754	El	10.5	1'x2'	12^h50^m	+11°35'
* NGC-4762	Sp	11.0	0.5'x4'	12^h50^m	+11°31'

* Detailed in Close-Up

BSp =Barred Spiral Galaxy
Mag. =Magnitude
Sep. =Separation
GC =Globular Cluster
Sp =Spiral Galaxy
El =Elliptical Galaxy

M-88

Just north of the heart of the Virgo cloud is M-88, a 10th magnitude spiral two by six minutes of arc in extent. It is more difficult to locate than its predecessors since it lies far from any bright guide stars. Look for it about midway between 6 and 29 Comae, four degrees south and slightly west of 24 Comae. Holyoke correctly considered it rather faint in a three inch.

Norton described M-88 as "a long, bright nebula . . . with bright center and condensation", and Muirden as an "elongated nebulosity, centrally condensed". The NGC notes it as "bright, very large, very much extended". Webb saw it as lying in a "marvelous region as swept with 64 (power)" on his 3.7 inch refractor and cautioned "identification difficult".

M-58, M-59, M-60

Before entering the actual core of this great cluster, we'll jump southeast of its center to another trio of Messier galaxies. Using Rho (ρ) Virginis (an apparent double star in the finder) as our anchor point this time, we find M-59 and M-60 1-1/2 degrees due north, lying together in the same telescopic field. M-60 is brighter and east of M-59; M-58 is just over one degree west and slightly north of M-59. The trio can be glimpsed in a three inch refractor at 45 power and are fascinating sights in six inch or larger instruments.

M-58 is a 9.2 magnitude spiral four minutes of arc in diameter. The NGC calls it "bright, large, irregularly round, very much brighter in middle, mottled". M-59 is an elliptical system measuring two by three minutes in size, and 9.6 magnitude. The NGC describes it as "bright, pretty large, extended, very suddenly much brighter in middle, two stars preceding". Also an elliptical, M-60 is two minutes in diameter and shines at magnitude 8.9, ranking it as one of the brightest Messier objects in the entire Virgo cloud. The NGC gives "very bright, pretty large, round, following of a double nebula".

Smyth also noted M-60 as a double nebula in his six inch refractor, for a faint spiral (NGC-4647) seems to nearly touch it. With small, bright M-59 a short distance to the west and a fainter elliptical below (NGC-4638), Smyth could see four galaxies in the same 93 power field of view! Webb could not see NGC-4647 in his 3.7 inch refractor, but noted that M-60 was "in a large field with M-59, north preceding, and NGC-4638 south preceding, like a hazy star".

NGC-4754 and NGC-4762

Midway between M-60 and Vindemiatrix is an interesting pair of NGC galaxies lying together in the same eyepiece field. NGC-4754 is a 10.5 magnitude elliptical one by two minutes in size, accompanied by NGC-4762, an 11th magnitude edge-on spiral four minutes long and less than 30 seconds of arc wide. Webb described the duo as being: "In one field. NGC-4762 like a paper kite; beautifully grouped with three stars." Other observers have described this needlelike object as a long ray with a nucleus. A four inch telescope at 45 power will show both objects on a dark night, but the paper kite aspect needs a larger aperture to be appreciated.

NGC-4567-68

Less than a degree south of M-58 is another NGC duo, this time so close together that they appear to touch each other! Dubbed the "Siamese twins" by Copeland, they were described by him as "a very dim spot in an eight inch telescope". They are NGC-4567 and NGC-4568, a pair of interacting spirals. The former is a circular glow two minutes in diameter, and the latter a two by four minute oval. Their combined light is about that of an 11th magnitude star out of focus. The NGC considers both of them "very faint, large" and as forming a double nebula. Medium to high magnification on an eight inch or larger telescope gives the best view of this unusual pair.

M-84, M-86, M-87, M-89, M-90

We come at last to the very heart of the Realm of the Galaxies, where we encounter no less than five Messier entities awaiting our thoughtful inspection. Three of them lie within 1-1/2 degrees of each other, at a point roughly 2/3 of the way from Rho Virginis to 6 Comae.

Easternmost of this trio is M-84, a one by two minute wisp of light glowing at magnitude 9.3. The NGC calls it "very bright, pretty large, round, pretty suddenly brighter in middle, mottled". Closest to M-84 and slightly north is M-86, shining at magnitude 9.7 and again one by two minutes in size. The NGC description here is very similar: "Very bright, large, round, gradually brighter in the middle to a nucleus, mottled." Holyoke saw both of these galaxies as "roundish and regular", and considered them quite easy in a six inch reflector. Both are elliptical systems and look like small fuzzy balls to most observers.

The third member of this trio is M-87, a giant elliptical 1-1/2 degrees southeast of the other two. It appears as an intense, circular ninth magnitude glow two minutes across and has a well-marked nucleus as seen at higher powers. The NGC calls it "very bright, very large, round, much brighter in middle, third of three".

M-87 has a strange jet of energized matter extending outward from its nucleus, as revealed by short exposure observatory photos. It has also been seen visually in very large telescopes like the 200 inch reflector at Palomar, where it is described by observers as "intensely bright". Apparently it has never been reported in large amateur instruments, though few observers have ever made a careful search for it. Long exposure photographs drown out the jet but show something equally remarkable — a vast spherical halo about this object made up of *thousands* of individual globular clusters!

Finally, M-87 is also an intense source of radio emission. Known as Virgo A, its signals are so strong that — despite its great distance from us — they can be picked up with homemade radio telescopes!

M-89 and M-90

Our final two offerings complete the roundup of Messier galaxies in this month's region. M-89 lies just over a degree east of M-87 (northwest of M-58), and is a ninth magnitude elliptical only one minute in diameter. Holyoke noted it as "small and rather faint", and requiring a good night to be seen with a three inch. The NGC gives "pretty bright, pretty small, round, gradually much brighter in middle".

Its companion is M-90, a spiral situated one degree north and slightly east; both objects fit within a low power eyepiece field. This diffuse, elongated blob shines at 10th magnitude and measures two by eight minutes in apparent size. The NGC describes it as "pretty large, brighter in middle to a nucleus". Both M-89 and M-90 need a six inch telescope to be appreciated.

Having paid our respects to some of the more notable denizens of these galactic depths, we get to the most thrilling aspect of the Realm of the Galaxies. Charge up your telescope with the lowest power, widest angle eyepiece available — something that will give you at least 1-1/2 degrees (three full moons) of actual field. Better yet, use a richest field telescope of at least four inches aperture with a three degree field.

Wait for a clear, mild, moonless April evening — preferably after a shower has cleansed the air — with Denebola and Vindemiatrix spanning the southern meridian like cosmic sentries. With your eyes well dark adapted, slowly sweep the sky back and forth between these stars, moving the telescope slightly north or south between scans. Passing in review before you will be a majestic profusion of universes upon universes — galaxies upon galaxies — clumped so thickly together in places that a dozen may be in view at the same time!

Such awesome rapture may well leave you speechless. Thus, even here in the far-flung Realm of the Galaxies, we find very real personal benefits attending stargazing. As the sage has so well observed, "The beginning of wisdom is silence."

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